THE QUARTERLY

JOURNAL OF SCIENCE.

APRIL, 1874.

I. ON THE FLINT AND CHERT IMPLEMENTS FOUND IN KENT'S CAVERN, NEAR TORQUAY, DEVONSHIRE.

By W. PENGELLY, F.R.S., &c.

ON the northern shore of the beautiful inlet of the English Channel known as Torbay, in Devonshire, stand the town and harbour of Torquay; and about a mile eastward from the harbour there is a small hill, consisting exclusively of limestone, and containing the celebrated Kent's Hole or Cavern. It is but little more than 200 feet above mean tide, whilst immediately on the south-west, and about half a mile to the north-west, rise two loftier eminences, known as Lincombe and Warberry Hills, consisting of grey shales and dark red grits, and reaching the heights of 372 and 450 feet respectively.

Though the cavern seems to have been well known at least three centuries ago, the attention of palæontologists and anthropologists was first directed to it by the labours and discoveries of the late Rev. J. MacEnery, of Torquay. In his "Cavern Researches," he says:—"In the summer of 1825, Dr. Buckland, accompanied by Mr. Northmore, of Cleve, visited the cave of Kent's Hole in search of bones. I attended them. Nothing remarkable was discovered that day, excepting the tooth of a rhinoceros and a flint blade. This was the first instance of the occurrence of British relics being noticed in this, or, I believe, in any other cave. Both these relics 'twas my good fortune to find."*

Towards the close of the same year, he commenced a somewhat systematic exploration of the Cavern, and, in the course of his researches, met with a considerable number of flint implements; and, believing the ground in which they were met with to have been previously broken up, he set himself seriously to work to ascertain whether or not they occurred under the undisturbed floor of stalagmite, covering

* Trans. Devon. Assoc. for the Advancement of Science, Literature, and Art, vol. iii., p. 441. 1869.

the loam or muddy deposit now known as Cave-earth. His description of this work is so graphic, displaying at once his mode of operation and his mental excitement, that I cannot refrain from quoting it :—

"Having cleared away on all sides the loose mould and all suspicious appearances, I dug under the regular [stalagmitic] crust, and flints presented themselves to my hand. This electrified me. I called the attention of my fellow-labourer . . . and in his presence extracted from the red marl arrow and lance-heads. I instantly proceeded to the excavation inside, which was only a few feet distant in the same continuous line, and formed part of the same plate—the crust is about two feet thick, steady (*i.e.*, of uniform thickness); the clay rather a light red. About three inches below the crust, the tooth of an ox met my eye: I called the people to witness the fact, . . . and not knowing the chance of finding flints, I then proceeded to dig under it, and at about a foot I dug out a flint arrow-head. This confirmation—I confess it—startled me. I dug again, and behold, a second! of the same size and colour (black). I struck my hammer into the earth a third time, and a third arrow-head, but white, answered to the blow. This was evidence beyond all question. I then desisted, not wishing to exhaust the bed, but, in case of cavil, leaving others an opportunity of verifying my statements by actual observation."*

The following is the substance of his further remarks on the subject :—The implements lay ordinarily between the bottom of the stalagmite and the upper surface of the cave-earth, but were occasionally, though rarely, buried a few inches deep in the latter, and mixed with the bones of the extinct cave mammals. None occurred in the stalagmite itself. Some were broken, and, as in the case of bones in a similar condition, the separated parts were found at some distance from each other. Instances were met with of indurated or coherent masses made up of Cave-earth, stones, fossil bones, and flint tools. In common with most observers of that time, he ascribed the introduction of the Cave-earth to the Deluge, and though, under the influence of Dr. Buckland, he finally expressed the belief that the implements were "post-diluvial," he contended that the facts just enumerated seemed "to countenance the opposite hypothesis;" though he was staggered by the belief that there were no implements in the cave-earth at depths exceeding a few inches, and no remains of the extinct mammals in the

* Trans. Devon. Assoc., vol. iii., pp. 329-30.

stalagmitic floor. His conviction was decided and firm that before the commencement of the formation of the stalagmite the tools occupied the place in which he discovered them; and when he found Dr. Buckland inclined to attribute them to a more modern date by supposing that the ancient Britons had scooped out ovens in the stalagmite, and that they had thus got admission to the cave-earth, he replied—"Without stopping to dwell on the difficulty of ripping up a solid floor, which, notwithstanding the advantage of undermining and the exposure of its edges, still defies all our efforts, though commanding the apparatus of the quarry, I am bold to say that in no instance have I discovered evidence of breaches or ovens in the floor, but one continuous plate of stalagmite diffused uniformly over the loam." "It is painful," he adds, "to dissent from so high authority, and more particularly so from my concurrence generally in his views of the phenomena of these caves, which three years' personal observation has in almost every instance enabled me to verify."*

Mr. Godwin-Austen, who, familiar with MacEnery's discoveries, had supplemented them with independent researches of his own, writes thus, in 1840:—"Arrow-heads and knives of flint occur in all parts of the cave, and throughout the entire thickness of the clay; and no distinction founded on distribution or relative position can be observed whereby the human can be separated from the other *reliquiæ*."† It is noteworthy, perhaps, that this important statement entirely removed the chief difficulty which MacEnery felt, in view of the hypothesis that man was, in Devonshire, contemporary with the extinct cave mammals. He believed that the flint tools did not occur at depths of more than a few inches in the cave-earth. It was reserved for Godwin-Austen to discover that, like the fossil bones, they were to be met with at all depths.

In 1846, a committee appointed by the Torquay Natural History Society carried on some very limited but most careful explorations in the Cavern; and make the following statement in their report, drawn up by Mr. E. Vivian, and read, the following year, to the Geological Society of London and the British Association:—"After taking every precaution, by sweeping the surface and examining most minutely whether there were any traces of the floor having been previously disturbed, we broke through the solid

* Trans. Devon. Assoc., vol. iii., pp. 334 and 338.
† Trans. Geol. Soc. of London, (2nd series), vol. vi., p. 444. 1842.

stalagmite in three different parts of the cavern, and in each instance found flint knives. . . . In the spot where the most highly finished specimen was found, the passage was so low that it was extremely difficult, with quarrymen's tools and good workmen, to break through the crust; and the supposition that it had been previously disturbed is impossible."*

Notwithstanding these repeated and concurrent announcements by independent and competent explorers, even the scientific world remained perfectly apathetic or altogether sceptical. Nor were they more influenced by the researches, with similar results, carried on in the caverns near Liège, by Dr. Schmerling, in 1833-34, or those of M. Boucher de Perthes in the river gravels of the Somme, a few years later. This strange apathy appears to have been based partly on the impression that the work had not been executed with sufficient care, and partly on the feeling that the belief respecting the date of the first appearance of man on the earth which held possession of almost every mind neither could nor should be disturbed.

Be this as it may, such was the attitude of most men of science up to 1858, when some quarrymen, in the ordinary course of their work, broke unexpectedly into a virgin cavern on Windmill Hill, Brixham, on the southern shore of Torbay. I almost immediately visited it, prevailed on the proprietor to discontinue the desultory excavations which he had begun, and secured from him the refusal of a lease in the cavern, in the hope that arrangements might be made for making a thorough and systematic exploration. It was soon after visited by the late Dr. Falconer, who, believing it might be capable of throwing light on certain palæontological problems then awaiting solution, prevailed on the Royal and Geological Societies of London to undertake the work. It was entrusted to a committee of the latter body, who placed it under my immediate superintendence as the only member residing in the district. The investigation was begun in July, 1858, and in the following September I was able to announce to the British Association, at Leeds, that in the new cavern flint implements had been found under an unbroken floor of stalagmite, deep in the cave-earth, and mingled with the remains of the ordinary extinct cave mammals. It was at once felt that the method and care which had been observed in the work rendered it impossible to doubt or to ignore the facts, or to resist the

* Report Brit. Assoc., 1847. Proceedings of the Sections, p. 73.

conviction that man had, in Britain, been the contemporary of animals which had become extinct, and that his first appearance was of higher antiquity than had generally been supposed.

In the autumn of 1858, the exploration at Brixham being still in progress, Dr. Falconer, having visited M. Boucher de Perthes, urged Mr. Prestwich to proceed to the valley of the Somme, and make a careful examination of the sections for himself. This was accordingly complied with, and the latter geologist, by embodying the results of his observations in a paper read to the Royal Society in May, 1859, may be said to have completed the revolution. Sir Charles Lyell, when opening the Geological Section of the British Association at Aberdeen, in September of the same year, not only announced his adhesion to the new opinion, but became one of its most powerful advocates; and so great and widely spread was the interest felt in the question that when, in 1863, he published his "Geological Evidences of the Antiquity of Man," he had the pleasure of placing the third edition of his work in the hands of the public before the end of the year.

It being felt to be on many accounts desirable to make a systematic exploration of the large branches of Kent's Cavern still remaining intact, the British Association, when assembled at Bath, in 1864, appointed a large committee to carry on the work, and placed at their disposal a considerable grant of money for the purpose. The investigation, under the immediate superintendence of Mr. Vivian and myself—the only two resident members of the committee—was commenced on 28th March, 1865; it has been continued to the present time, and is still in progress. Nine annual reports have been sent in to the Association and ordered to be printed, and ample grants of money have been voted every year.

It is my object in the present paper to state what stone implements have been discovered in the cavern, and to call attention to the fact that whilst all the noteworthy specimens are unpolished, and found with the remains of extinct mammals, they belong to two distinct classes, eras, and stages of civilisation.

Though there are said to be persons capable of believing that the so-called stone implements found in Kent's Hole and other caverns, as well as in the river-gravels, are merely natural products, it is not my intention to say one word on that question. It has been treated so fully and so ably by various writers as to deprive me of any pretence for attempting

to add anything to the literature of the subject, and also of any hope that such additions as I might be able to make would have the least effect on those still remaining in a sceptical state.

It may be as well at the outset to describe the successive deposits, and their principal contents, met with in the cavern during the exploration now in progress. They are as follow, in descending order:—

1st, or uppermost. Blocks of limestone, from a few pounds to upwards of 100 tons each, which had fallen from the roof from time to time, and were in some instances cemented together with carbonate of lime.

2nd. Beneath and between the blocks just mentioned lay a dark-coloured mud, consisting largely of decayed leaves and other vegetable matter, from 3 to 12 inches thick, and known as the *Black Mould*.

3rd. Under this was a stalagmitic floor, commonly of granular texture, varying from an inch or even less to upwards of 5 feet in thickness, frequently containing large blocks of limestone, and termed the *Granular Stalagmite*.

4th. An almost black layer, about 4 inches thick, composed mainly of small fragments of charred wood, and distinguished as the *Black Band*, occupied an area of about 100 square feet, immediately under the granular stalagmite, and, where nearest to it, about 32 feet from one of the entrances to the cavern. Nothing resembling it was found elsewhere.

5th. Immediately under the Granular Stalagmite and the Black Band, lay an accumulation of light red clay, containing on the average about 50 per cent of small angular fragments of limestone, and somewhat numerous blocks of the same materials as large as those already mentioned as lying on the Black Mould. In this deposit, known as the *Cave-earth*, many of the stones and osseous remains were, at all depths, invested with thin stalagmitic films; and it occasionally contained large isolated masses of stalagmite having a very crystalline texture, sub-angular and rounded fragments of quartz and dark red grit sometimes cemented into more or less round detached lumps of firm concrete, and a very few granitoid pebbles. The Cave-earth was usually of unknown depth, certainly and perhaps greatly exceeding 4 feet, but it was occasionally much less, and in some instances there was none.

6th. Wherever the bottom of the Cave-earth was reached, there was found beneath it a floor of stalagmite having a

crystalline texture, identical with that of the isolated masses just mentioned as being incorporated in the Cave-earth. This, designated the *Crystalline Stalagmite*, was usually of greater thickness than the upper or granular floor, in the same branch of the Cavern, and was in some instances but little short of 12 feet. Where there was no Cave-earth, the two stalagmites lay one immediately on the other.

7th. Below the whole occurred, so far as is at present known, the lowest and oldest of the deposits which the Cavern now contains. It was composed of sub-angular and rounded pieces of quartz and dark red grit, the latter being the more prevalent, embedded in a sandy paste of the same colour. Small angular fragments of limestone, and thin investing films of stalagmite, both prevalent in the Cave-earth as already stated, were extremely rare; large blocks of limestone were occasionally met with, and the deposit, to which the name of *Breccia* has been given, was of a depth exceeding that to which the exploration has yet been carried.

The masses of Crystalline Stalagmite and the fragments and lumps of dark red grit found embedded in the Cave-earth are undoubtedly portions, not *in situ*, of the two older deposits—the Crystalline Stalagmitic floor and the Breccia—and show that these accumulations had been broken up by some natural agency at least partially before the introduction of the Cave-earth into the Cavern, and that they were formerly of greater volume than at present.

Excepting the overlying blocks of limestone (No. 1), which need not be mentioned again, all the deposits contained remains of animals. In the Black Mould, the most modern accumulation, they were those of species still existing, and almost all of them now occupying the district. They were man, dog, fox, badger, brown bear, *Bos longifrons*, roe-deer, sheep, goat, pig, hare, rabbit, water-rat, and seal.

In the Granular Stalagmite, Black Band, and Cave-earth, extinct as well as recent species presented themselves. The cave-hyæna was the most prevalent, but was followed very closely by the horse and rhinoceros. Remains of the so-called Irish elk, wild-bull, bison, red-deer, mammoth, badger, the cave, grizzly, and brown bears, were by no means rare; those of the cave-lion, wolf, fox, and reindeer were less numerous; and those of beaver, glutton, and *Machairodus latidens* were very scarce. The presence of the hyæna was also announced by his coprolites, by bones broken after a manner still followed by existing members of the same genus, and by the marks of his teeth found on a very large proportion of the osseous remains.

In the lowest deposits—the Crystalline Stalagmite and the Breccia—remains of animals were less uniformly distributed. In some instances there were none throughout considerable volumes of the deposits, whilst in others they were so numerous as to form 50 per cent of the entire deposit. To use the language of one of the workmen employed in the exploration, "they lay about as thick as if they had been thrown there with a shovel." So far as is at present known, they were exclusively the remains of bears. Not only were there no bones of the hyæna, there were none of his fæces, none of his teeth-marks, no bones fractured according to his well-known pattern,—nothing whatever to indicate his existence.

The bones found in the uppermost deposit—the Black Mould—were of much less specific gravity than those in the accumulation below it, and were generally so light as to float in water. Those in the two sets of deposits represented by the Cave-earth and the Breccia respectively, had lost their animal matter, and adhered to the tongue when applied to it so as frequently to support their own weight; but those from the Breccia and its Stalagmite—the lowest deposits—were distinguished from those of the Cave-earth series in being much more mineralised, more brittle, and by frequently emitting a metallic sound when struck.

The following general statements may be of service, by way of recapitulation, before proceeding further:—

1st. The Cavern contained three distinct mechanical accumulations—the Black Mould, or uppermost, or most modern; the Cave-earth, including the local Black Band; and the Breccia, or lowermost, or most ancient. Their mode of succession was never transgressed, and the materials of which they consisted were so very dissimilar as to characterise them with great distinctness.

2nd. These three accumulations were separated by two distinct floors of stalagmite having strongly contrasted characters. That dividing the Black Mould, or uppermost deposit, from the Cave-earth was granular; whilst that lying between the Cave-earth and Breccia, or lowermost deposit, was eminently crystalline.

3rd. Animal remains occurred everywhere, but were much more abundant in the mechanical deposits than in the stalagmites.

4th. The period represented by the Black Mould—the most modern period—may, as a matter of convenience, and so far as the Cavern is concerned, be termed the *Ovine period*, remains of sheep being restricted to this accumulation.

5th. The period of the Granular Stalagmite, Black Band, and Cave-earth may be denominated the *Hyænine period*, the remains of hyæna being confined to these deposits, and more prevalent there than those of any other species.

6th. The period of the Crystalline Stalagmite and Breccia —the most ancient period represented by the Cavern deposits so far as they are at present known—may be called the *Ursine period*, these deposits having yielded remains of bear only. It must be understood, however, that bears are represented in all the deposits.

7th. The bones of each period were distinguishable by their condition; those from the Black Mould being lighter, and those found in the Breccia being more mineralised, than the products of the Cave-earth.

Flint and chert implements presented themselves in each of the mechanical deposits, and, as in the case of the bones, those belonging to any one of them were easily distinguishable from those of the other two.

The implements of the Black Mould—the Ovine, or most modern period—were of the ordinary colour of common flints. They were mere flakes and "strike-lights," the latter probably used and cast aside or lost by those who, during a long period, and before the invention of lucifer-matches, acted as guides to the Cavern. All further mention of them may be omitted as not being noteworthy.

Omitting mere flakes and chips, of which there were great numbers, the principal implements found in the Cave-earth—the Hyænine period—were ovoid, lanceolate, and tongue-shaped, produced by fashioning, not flint or chert nodules, but flakes struck off them for the purpose. They were of comparatively delicate proportions; those of flint were usually of a white colour and porcellanous aspect, and having, through metamorphosis, a granular chalk-like texture.

These are not the only human industrial remains found in the Cave-earth, as it has yielded a bone needle or bodkin with a well-formed eye, three bone harpoons or fish spears—one of them barbed on both sides, and the others on one only—a bone pin, a bone awl, hammer stones, "whetstones," charred bones and wood, and a badger's canine tooth having its fang artificially perforated apparently for the purpose of being strung with other objects to form a necklace or bracelet—an indication that the cave men of the Hyænine period occupied themselves in making ornaments as well as objects of mere utility.

The implements from the Breccia—the Ursine, or most ancient of the periods—were much more rudely formed,

more massive, less symmetrical in outline, and made by operating, not on flakes, but directly on nodules, which appear to have been derived from supracretaceous gravels between Torquay and Newton Abbot, about four miles from the Cavern, and generally retain portions of the original surface. It is obvious, however, that even such tools could not be made without the dislodgement of flakes or chips from the nodule, and, accordingly, remnants of this kind have presented themselves in the Breccia, but they are all of a very rude character. There was also a mass of flint which may have been a "core" from which flakes had been struck, or, what seems not less probable, the useless result of an abortive attempt to make a tool.

No such implements have been found in the Cave-earth, nor have any of the comparatively slender, symmetrical tools of this less ancient deposit been found in the Breccia. They are by no means so abundant as those of the Cave-earth; that is to say a given volume of Breccia has not yielded so many implements as would on the average occur in an equal volume of the more modern accumulation. Whether equal periods of time are represented by equal volumes of deposit in the two cases, or whether equal periods of time represent equal numbers of human cave dwellers or tool-makers in the two eras, are questions which present themselves, but into which it is not possible to go fully at present. Omitting rude flakes and chips as well as the "core" or "failure" just mentioned, the Breccia has up to this time yielded no more than eleven specimens of the kind. It must be remembered, however, that the time during which the explorers have been excavating the Breccia is comparatively short. The implements just mentioned are the only indications of man which have been found belonging to the Ursine period.

That the implements from the Breccia belonged to an earlier period than those from the Cave-earth is obvious from the position they occupied; they were lodged in a deposit which, when the two were found in the same vertical section, invariably underlay the Cave-earth. In fact, every tool found in the Breccia actually had Cave-earth above it.

That the two periods were separated by a great chronological interval is indicated by the geological and palæontological facts, and the considerations growing out of them:—

1st. The Breccia and the Cave-earth, though deposited on the same area, were very dissimilar, as has been stated; the former consisting of a dark red sandy paste containing a very large number of sub-angular and rounded fragments of dark

red grit, which, though derivable from the adjacent and loftier eminences, the Cavern-hill could not supply; and the latter, or more modern, being made up of a light red clay with small angular fragments of limestone.

2nd. These two deposits were separated by a sheet of Crystalline Stalagmite, in some places almost 12 feet thick, formed after the materials of the Breccia had all been introduced, but before the introduction of the Cave-earth commenced.

3rd. After the Stalagmite just mentioned had sealed up the Breccia, it was in extensive parts of the Cavern, broken up by some natural agency, and much of the underlying Breccia was dislodged and carried out of the Cavern, before the first instalment of Cave-earth was deposited.

4th. The Cavern faunæ during the two periods were very dissimilar: that of the Breccia did not include the hyæna, which played so conspicuous a part in the Cavern history during the subsequent Cave-earth era, and whose agency, next to that of man, made cavern searching an important branch of science. When his cavern-haunting habits are remembered, it will be seen that his absence in the one fauna, and his presence in the other, render it eminently probable that he was not an occupant of Britain during the earlier period.

The same inference cannot with an equal approach to certainty be drawn respecting the horse, ox, deer, &c., though the absence of their remains from the Breccia is equally pronounced; for it may be presumed that their bones occur in caverns simply because their dead bodies were dragged there piecemeal by the hyæna, and this could not have occurred, even though they had crowded the country, before the arrival of the great bone-eating scavenger who made the Cavern his home.

The remains of the bear in the Breccia present no difficulty, for their introduction did not require the agency of the hyæna, since the bear is a cave-dweller. Dr. Leith Adams, F.R.S., so well known as a naturalist and cavern explorer, writing me on the subject, says:—"The Brown Bear of the western Himalayas hybernates, choosing chiefly caverns and rock crevices, which it abandons in spring to wander about; but old individuals, when no longer equal to the same amount of exertion, take to a secluded life, and usually select a cavern on a rocky mountain side, at the base of which there is abundant verdure and shade, with a pool or spring where they bathe frequently, or recline during the heat of the day to escape the annoyance of insects. Such

retreats are easily discovered by the animals' footprints on the soil and turf. They are seen like steps of stairs leading from the pool in the direction of the den, being brought about by the individual always treading in the same track. Thus the patriarch or hermit bears spend their latter years in one situation, pursuing the even tenor of their ways to the little stream or pond below, and grassy slopes, to feed on the rank vegetation, returning regularly to the caverns, where they end their days."

5th. The deposits just described are obviously not only distinct, successive, and protracted terms in the Cavern chronology, but indicators of changes in the conditions of the geographical features of the immediately surrounding country, and of the relation of the Cavern to it. During the period of the Breccia there was a machinery capable of transporting from Lincombe hill, or Warberry hill, or both, or from some greater distance, fragments of dark red grit, varying in size from pieces four inches in mean diameter to mere sand, and lodging them in the Cavern. This so completely passed away that nothing was carried in; but the deposit, already there, was covered with a thick sheet of Crystalline Stalagmite obtained through the solution of portions of the limestone in the heart of which the Cavern lay. This also ended: the stalagmite was broken up by some natural agency, apparently not by one effort, but by many in succession, and much of the Breccia was dislodged and carried out of the Cavern. This having in like manner come to a close, again a deposit was introduced; but, instead of being dark red stones and sand, as in the former instance, it was a light red clay; and in it were embedded small fragments of limestone, which, from their angularity, could not have been rolled, but were in all probability supplied by the waste of the walls and roof of the Cavern itself. It contained also the bones of numerous species of mammals, and of these the remains of the hyæna were the most prevalent.

Nor is the palæontology of the two periods less significant of physical charges. If the absence of any traces of the hyæna from the older deposit has been correctly interpreted above, as signifying that the species was not then an occupant of Britain, it follows that it was subsequently possible for him to arrive here, or, in other words, Britain had become connected by dry land with the Continent. In short, the facts point to the conclusion that the earliest Devonshire men known to us—the men of the Ursine, the Breccia period—saw this country an island as we see it, and that in

the time of their descendants, or their successors, prior to the Hyænine or Cave-earth era, it had reached a continental condition. This latter condition has so long ceased that the earliest traditions respecting our land recognise it as an island, even though they profess to go back to a time when Anglesea was not yet detached from Wales.*

Readers of Sir C. Lyell's "Antiquity of Man" are aware that he recognises two distinct periods in geologically recent times when Britain was in a continental condition. He supposes that the well-known "forest of Cromer," in Norfolk, in which Scotch and spruce first were prevalent, flourished at the close of the first of them; that in the intervening period, the land north of the Thames and Bristol Channel was gradually submerged until a few mountain tops alone remained above the sea; and, from the evidence then available, that the first appearance of man when . . . . he ranged from all parts of the Continent into the British area, took place during the second continental period."†

If, however, the new evidence from Kent's Cavern has been correctly interpreted above, the first appearance of Man in Britain was prior to the second continental period, and must have been at least as early as the previous insular era. Indeed, unless we suppose him to have possessed the means of navigation, it must have been in the first continental period.

It is worthy of remark that the hypothesis that the land south of the Thames and Bristol Channel was not submerged during the interval separating the two continental periods, harmonises well with the supposition that Devonshire was occupied by man during that interval.

Without at present attempting to pursue further the question of the relation of the oldest Devonshire men yet known to Glacial times, I cannot divest myself of the belief that the complete exploration of Kent's Cavern will furnish a definite reply to it.

Though no one acquainted with the present state of the evidence would attempt to express in years, or other astronomical units, the amount of time represented by the deposits of the Ovine and Hyænine periods, it cannot be doubted that the spindle whorls, the pottery, the bone combs, and the fibulæ of the Black Mould—the first or uppermost of these—go back to Romano-British and Pre-Roman times, to at least two thousand years from the present day as a minimum. All that is known about the Granular Stalagmite—

* See the 67th of the Historical Triads of Britain.
† Antiquity of Man, pp. 282-3.

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the preceding term of the series—points to the conclusion that it was formed slowly. That the main lines of drainage through the roof have remained unaltered is seen in the facts that those parts of the cavern which have an unusually thick floor of stalagmite have also, at present, more than an ordinarily copious drip; where the floor is but thin the drip is never of great amount; and where there is no floor—for a few such places occur—the cavern is quite dry at all seasons; and further, wherever a conspicuous stalactite depended from the roof, there was found, vertically below, rising from the Granular Stalagmitic floor a considerable boss of the same material to meet it; and whenever the lower or Crystalline Stalagmitic floor was found in such a section, a similar but larger boss existed on it also. In several parts of the Cavern there are names, initials, and dates inscribed on the Granular Stalagmite, where it is certainly of great thickness, and where additions are still being made to it. There is satisfactory evidence of their genuineness; and, though some of them are upwards of two hundred and fifty years old, and are slightly glazed over, they are perfectly legible, and the film accreted on them cannot be more than the twentieth of an inch in thickness. It is not pretended, of course, that this rate *must* be taken as a trustworthy chronometer for the entire thickness, but those who object to it must expect to be called on to state why they do so; and even if the objection should be sustained, it will be seen that, when a thickness of five feet presents itself for measurement—a rate even ten times as great as that which has certainly obtained for more than two and a half centuries—betokens a great antiquity.

That the Cave-earth, every portion of which is necessarily older than the most ancient part of the stalagmite covering it, was accumulated very slowly is seen in the great number of small angular fragments with which the walls of the cavern have crowded it, and in the films of stalagmite which, as already stated, invest the bones and stones everywhere throughout the total depth of the mass, since each such film indicates that the spot the invested object occupies was a portion of the floor of the Cavern during a time sufficient for its accretion, and that it was only prevented from growing into a thick wide-spread sheet by the introduction and lodgement on it of a small instalment of Cave-earth.

Whatever be the aggregate amount of time represented by the less ancient deposits just spoken of, there can be little doubt that at least fully as much is absorbed by the more ancient cavern history, of which the formation of the Breccia and Crystalline Stalagmite, as well as the subsequent

destruction and dislodgement of great portions of these, are the exponents. It may be true that the Breccia was introduced at a more rapid rate than the Cave-earth; and, indeed, this is rendered not improbable by the great paucity of angular fragments of limestone, as well as of films of Stalagmite in the older deposit; but this is probably more than neutralised by the immense thickness of the Crystalline or older Stalagmite as compared with that of the Granular or more modern; the former being in one chamber but little short of 12 feet, whilst the latter has in no instance much exceeded 5 feet.

In short, and speaking for myself, however far back in antiquity the fabricators of the Cave-earth tools take their stand, I cannot hesitate to place those of the implements of the Breccia as much further back. Many must remember, and perhaps few were surprised at, the alarm occasioned by the antiquity of man disclosed by the researches in Brixham Cavern, in 1858; and now, cavern researches, growing out of those just mentioned, appear to me to make an irresistible demand to have human antiquity in Britain at least doubled.

Up to the present time, as the Cavern has disclosed more and more ancient men, it has shown that they were ruder and ruder as they withdrew into antiquity. The men of the Black Mould had a great variety of bone implements, they used spindle whorls, and made pottery, and smelted and compounded metals. The older men of the Cave-earth made a few bone tools, they used needles, and probably stitched skins together, and even perforated badgers' teeth to enable them to be strung as necklaces or bracelets, but they had neither spindle whorls nor pottery, nor metals of any kind; their most powerful weapons were made of flakes of flint and chert, many of them symmetrically formed and carefully chipped, but it seems never to have occurred to them to increase their efficiency by polishing them. The still more ancient men of the Breccia have left behind them not even a single bone tool; they made implements of nodules, not flakes, of flint and chert; tools that were rude and massive, had but little regularity of outline, and were but roughly chipped.

It has not been unusual to hear the men of the Cave-earth period spoken of as *Primeval Men*, or *Aborigines of Devonshire;* the discovery of men of higher antiquity in the same area is at once a proof that the names are inappropriate, and a warning against applying them to even the men of the Breccia; for, though these are no doubt the oldest men yet known to us, they hint that further discoveries may yet be made.

II. ON RECENT EXTRAORDINARY OSCILLATIONS OF THE WATERS IN LAKE ONTARIO AND ON THE SEA-SHORES OF PERU, AUSTRALIA, DEVONSHIRE, CORNWALL, &c.

By Richard Edmonds.

THESE tide-like alternating currents, which resemble in all respects those observed on the shores of this and other countries on the days of the two great earthquakes of 1755 and 1761, commence generally, if not always, with an efflux, and occupy from five to ten minutes in ebbing, and about the same time in flowing, the ebb and flow and the imperceptible interval between them never exceeding twenty minutes. Those on the 5th of July, 1843, were observed between the hours of 11 a.m. and 5 p.m. in Plymouth, Falmouth, Mountsbay, the Scilly Isles, Bristol, and on the eastern coast of Scotland at North Berwick and Arbroath. Those of the 29th of September, 1869, occurred on the northern as well as on the southern coasts of Devonshire and Cornwall, and at the Scilly Isles. Of these and all the intermediate ones of importance in these two counties I have written full descriptions, including all meteorological particulars.*

These currents, when running in and out of piers or narrow channels, often drive vessels from their moorings, and dash them against one another. But when they are moving up and down a wide open beach, the motion is so quiet and tide-like that they would not be perceived unless they were watched for some time. This was amusingly exemplified at Penzance, when, during such an oscillation, some children who had been long enough on the beach to discover it made a play of their discovery, by inducing other children who had not observed it to go out on some rocks left dry by an efflux, where they were soon surrounded, and for many minutes in a great fright lest they should be drowned.

Such is the nature of these extraordinary oscillations *after the first efflux*, whether on sea-shores or on the shores of lakes. The *first efflux* is well illustrated by that in Lake

* See "Literary Gazette" of June, 1843; The "Edinburgh New Philosophical Journal," 1845, and following years until it merged into the "Quarterly Journal of Science;" and the "Philosophical Magazine" for January, 1866, and January, 1869.

Ontario on the 13th of June, 1872, as related in the "Rochester Democrat" of the 15th of that month. While some gentlemen of Rochester were in a boat near the beach, "where the water is usually 2 feet deep at least, their boat suddenly grounded, and the waters receding left her on a sand-bank. The gentlemen got out and strolled away, but looking back shortly after, they saw to their surprise the boat dashing about in apparently deep water. Securing the boat with some difficulty, they found her suddenly aground again, and as suddenly floated after a short interval. Becoming now interested in this curious ebb and flow of the lake, they diligently observed it for about three hours. *The ebb and flow occurred every twenty minutes, that is, for ten minutes the water would gradually recede, then commence rising, and continue to rise for about ten minutes. The water rose 2 feet and 3 or 4 inches above the ordinary level, then receded about the same distance below the usual level, making a variation in the height of the water of nearly or quite 4½ feet every twenty minutes.*" The above quotation is from the "Croydon Chronicle" of July 13, 1872, and what I have italicised is also a quotation from an abbreviated notice in the "Times" of the same date.

There was a similar occurrence in this lake on the 20th of September, 1845, when the waters suddenly moved "in a mass out of the rivers, bays, coves, harbours, &c.," to a depth of 2 feet, and then returned to an equal height above their previous level. This happened on each side of the lake.*

The explanation of these phenomena, whether in lakes or on the shores of the sea, I have given in the "Transactions of the Royal Geological Society of Cornwall" for 1843, and as it is the only one yet proposed that can reconcile all the observed facts connected with them, I will now give it more fully, and with the addition of some recent confirmatory facts.

My hypothesis is that an earthquake shock proceeding upwards vertically from the interior of the earth reaches the basin of the lake. Now wherever this basin is horizontal the shock continues its vertical ascent up through the water as through a solid body, and with greater velocity than the most rapid flight of a cannon-ball; but none of the water is thereby displaced except the surface, which, as will be presently exemplified, is dashed up vertically and then falls back into its previous place, no current being produced. If a ship were on the spot, it would receive the shock, and

* Edinburgh New Phil. Journal for July, 1848, pp. 107-109.

loose pieces of timber, or anchors lying on the deck, and even men standing on the deck, as will also presently be shown, would be jerked up to heights proportioned to the violence of the shock. Much of the basin of the lake, however, is not horizontal, but sloping from its shores. Therefore when the shock which had proceeded vertically up from the interior of the earth reached the inclined or sloping sides of the basin, it would not continue to proceed up through the incumbent water vertically or perpendicularly to the horizon, but perpendicularly to the inclined plane of the basin, whereby the surface water dashed off would be jerked towards the centre of the lake. What I have called an earthquake-shock is really, however, only a single vibration of an earthquake-shock; for an earthquake-shock consists usually of a rapid succession of vibrations, sounding at *sea* "like the letting out of a cable," and on *land* "like a waggon rushing over a paved road." By such vibrations, therefore, from the sloping sides of the basin, even if there were only five or six in a second, and the shock lasted only 30 seconds, a great heap of water would be raised. The first vibration would, as I have said, jerk the surface water towards the centre of the lake, and before this dashed off surface water had time to flow back to its place, fresh surfaces would be jerked in the same direction by succeeding vibrations, so that the successive surfaces, whilst being thus dashed off, would form a current towards the centre, to supply which an efflux from the shores would necessarily follow. This efflux would not cease until the vibrations ceased, and then the heaped-up waters would immediately flow back to the shores. The subsequent ebbings and flowings, like the oscillations of a pendulum, would continue until the equilibrium were restored.

The extraordinary movements of the waters so often observed in the American lakes, though not always of the same description as the two in Lake Ontario above given, may all, I think, be accounted for by my hypothesis. For example, if the earthquake shock in the bed of the lake be very partial, and do not occur on its sloping sides, but only on shoals near its centre—say two hills, or two parallel ridges, with sides inclining down into the intermediate valley—then the waters driven from these opposite sides would meet over the valley and form a high wave, which might flow on to the shore and rush up without any previous efflux beyond that slight and momentary retirement of the water which always precedes the fall of a wave on the shore.

I have said that a vertical shock proceeding from a

horizontal portion of the basin of a lake occasions no current, because the surface of the water is thereby jerked up in jets perpendicular to the horizon, which jets fall back into the places they had previously occupied. An illustration of this appears in the following extract from the "Times" of October 18, 1869, describing the effects of a vertical shock from a horizontal portion of the bed of the sea, over which a ship was then passing:—"A correspondent writing from Valparaiso, on 3rd September, 1869, says, 'I arrived here on the 28th ult, in the steam ship "Payta," from Callao. . . We left Arica in the morning of the 24th ult., and at 1.20 p.m. (the "Payta" being two to two and a half miles from the land, fifty seven miles south of Arica, off Gorda Point, and in seventy-five fathoms of water), the vessel commenced to shake in the most awful manner, making it impossible to keep one's footing. (In another account in the same day's paper by the purser of the "Payta," it is stated that 'the vibration threw the passengers to the height of two inches* above the deck'). This convulsed vibration continued 45 or 50 seconds, during which time the sea presented the appearance of a heavy fall of large hailstones, *sending up jets of water* some eight or ten inches, and being about the same distance apart. On arriving at Iquique the same night, we learnt that two very severe shocks of earthquakes had been felt there about two o'clock in the day." Had this vertical shock off Gorda Point proceeded from an inclined shore, the jets of water, instead of being jerked up vertically, and falling back into their previous places as they did, would have been jerked up obliquely in a seaward direction, rising so little above the surface that the separate jets would not be distinguishable, and the entire surface would have been seen as a vast current rushing *seaward*, so long as the vibrations continued; and, when they ceased, the heaped up water would return *shoreward* to find its level.

We have seen that in Lake Ontario, in 1845, as well as in 1872, the water first retired to a depth of two feet or more, and then returned to an equal height above its previous level, just as a *harp-string or pendulum, when moved to any distance from its point of rest, will immediately of itself move twice such distance in the opposite direction.* This applies to marine as well as to lacustrine disturbances. Luke Howard, describing those at Plymouth on the 11th of May, 1811, says: "the sea fell instantaneously about four feet, and

* Lyell records an instance of men on board a ship forty leagues west of Cape St. Vincent being thrown by an earthquake shock "a foot and a half perpendicularly up from the deck."

immediately rose about eight feet." Those "mountainous" waves, therefore, which overwhelmed the Peruvian cities of Iquique and Arica, on the 13th of August, 1868, were nothing more than might have been anticipated from the illustration by the harp-string and pendulum. For the great wave, *forty feet high*, which completed the destruction of Iquique (directly after the earthquake shock had laid it in ruins) was immediately preceded by a retirement of the sea to the extraordinary depth of *four fathoms*. It was by a still higher wave, arising from an apparently still greater retirement of the sea, that Arica was destroyed, as appears from the following account given by Mr. Nugent, H.M. Vice Consul, in the "South American Missionary Magazine" for October, 1868. "In the afternoon of August 13, 1868, about 5 o'clock, we were visited with a most tremendous earthquake. I had scarcely time to get my wife and children into the street, when the whole of the walls of my house fell, or rather were blown out, as if *jerked* at us. I started over the *trembling ground* for the hills. . . . A great cry went up to heaven, such as few men have heard, 'The sea is retiring.' . . I looked back. . . . I saw all the vessels in the bay carried out irresistibly to sea (anchors and chains were as packthread), probably with a speed of ten miles an hour. *In a few minutes the great outward current stopped, stemmed by a mighty rising wave*, I should judge about *fifty feet high*, which came on with an awful rush, bringing in the whole of the shipping with it, sometimes turning in circles as if striving to elude their fate. . . . The wave passed on, struck the mole into atoms, swallowed up the Custom-House, . . . carried everything before it. In a few minutes all was completed—every vessel was either ashore or bottom upwards." "*The mighty rising wave*" here described was evidently the accumulation produced by "*the great outward current*," and that *outward current* was caused by "*the trembling ground*" beneath the sea, that is by the rapid vibrations of the inclined bed of the sea descending from the shore; for as the dry land was then "*trembling*" or vibrating by the vertical shock, the adjoining submarine ground must have been so also. This is a fair specimen (although on a terribly large scale) of all those extraordinary agitations now under consideration.

Mr. Mallet, however, entertains the idea proposed by Michell a century ago, that these extraordinary *influxes* proceed from the offing, and from vast but very low waves formed by submarine earthquakes or volcanos at the distance

sometimes of thousands of miles,* instead of their being merely the reaction, the rebounds or *refluxes* of the immediately preceding *effluxes* occasioned, as I have shown, by *local* submarine earth-*shocks*. And writers in some of our leading periodicals†, having adopted the same idea, have ascribed the extraordinary disturbances of the Sea in California, New Zealand, Australia, and other islands in the Pacific, on the 13th and 14th of August, 1868, immediately after the destruction of Arica, to one of these great sea waves produced by a submarine earthquake near Peru, and moving onwards in all directions with varying velocity (like other great sea waves) according to the square roots of the varying depths which they traversed. But such waves are only imaginary; they have never been seen, nor can their existence be proved. None such existed at any of the similar agitations in the West of England which I have described during the last thirty years; and, therefore, none such can be rightly assumed to have existed at any other similar agitations. To remove all doubt, however, on this point, I invite attention to what was observed at Plymouth, on the 29th of September, 1869, during the extraordinary disturbances of the sea that day, on the northern as well as on the southern coasts of Devonshire and Cornwall. *Ex uno disce omnes.*

The alternating current in Cattewater, an anchorage outside Plymouth pier (Sutton Pool), rushed in and out of the pier every 15 or 20 minutes, whirling about the boats and vessels, parting their hawsers, and carrying a schooner which had almost reached the pier back two or three furlongs, and then to and fro so helplessly that a steam tug was despatched to her assistance, and towed her in. This commotion was almost universally believed to have come in from the offing, through the two entrances at the ends of the breakwater. I was sure from past experience that it did not, and so it proved. One of the keepers of the lighthouse on the breakwater, and one of the labourers there, informed me that they were on the breakwater all that day, and that the sea there was quite undisturbed. Moreover, the foreman of the labourers, who was absent that day, told me that, after having witnessed the extraordinary disturbance in Cattewater, he was so convinced of its having proceeded from outside the breakwater, that he fully expected, when he

* Quarterly Journal of Science for January, 1864.

† See the articles on Earthquakes in the "Times" of November 3, 1868, and the "British Quarterly Review" for January, 1869, and "Blackwood's Edinburgh Magazine" for July, 1869.

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went thither, to find all his recent unfinished work washed away. But on arriving at his work the following day, and finding it precisely as he left it, and hearing from his men that the sea had been all the time of his absence quite undisturbed, this unexpected information was to him just as marvellous as the phenomenon itself in Cattewater.

The only possible cause of the disturbances of the sea this day, on the northern as well as on the southern coasts of Devonshire and Cornwall, and at the Scilly Isles, appears to be local submarine vertical shocks, not rising higher than the bed of the sea.

These phenomena are never, as I consider, occasioned by *undulatory* earthquakes, but only by vertical shocks. During the earthquake at Antioch, on the 3rd of April, 1872, "so long as the *undulatory* motion continued, no houses fell, but as soon as *vertical* jerks set in, a large part of the town was in a few seconds a heap of ruins."* Providentially these vertical shocks, proceeding from the deep interior of the earth, do not generally rise higher than the basins of lakes, or the bed of the sea. Thus, on the day of the great earthquake of 1755, whilst only one shock was perceived on the surface of the mines in Derbyshire Peak, five smart ones were felt sixty fathoms underground†. On the same day, not only Lochness and other lakes in Scotland, but even ponds in England, were violently agitated without any perceptible shock in their neighbourhoods.

III. THE NATIVE COPPER MINES OF LAKE SUPERIOR.

By James Douglas, Quebec.

THE Jesuit fathers who, in extending the domain of Christianity two centuries ago, explored and described parts of the American continent, which are still almost as wild as then, likened Lake Superior to a relaxed bow on whose string rests an arrow, the north or Canadian shore being the bow, the south or United States shore the bow-string, and the arrow the promontory of Keweenah, which, protruding from the south shore far across the lake, divides its waters almost into halves. This promontory,

* Times of July 30, 1872.
† Phil. Trans., 49, p. 398.

while one of the most salient geographical features of the lake, is moreover geologically and mineralogically the most remarkable, for on it, running from end to end, exist in their greatest development those cupriferous beds of trap and conglomerate in which native copper occurs under conditions most puzzling to the mineralogist, and from which it is being extracted in quantities sufficient to supply the growing wants of the United States and to threaten the stability of the copper market elsewhere.

In the present article, it is not my object to discuss the cosmical bearing of the subject, but to describe two of the most noted mines near Portage Lake and the means adopted to extract the mineral from their ores. Nevertheless, a sketch of the geology of the region and of the mining elsewhere in it is necessary as a preface. Lake Superior is framed in primitive rocks. The gneisses and granites of the Laurentian formation at places rise in bold cliffs out of the waters along the east and north shores, and where the shore line in its trend to the south-west leaves the Laurentides, the intervening space is occupied by a narrow belt of Huronian slates and conglomerates, on which seem to rest unconformably, judging from the scanty evidence afforded by the survey of this part of the north shore, but conformably, according to Brookes and Pompelly,* who have examined the lines of contact on the south shore, a series of beds of bluish shale, sandstone, indurated marls and conglomerates, interstratified with trap, which is sometimes amygdaloidal.

Sir William Logan subdivides this great mass of rock, whose total thickness can be but vaguely guessed at, into lower and upper groups, and designates them as the upper copper-bearing rocks of Lake Superior, in distinction to the Huronian or lower copper-bearing series.

The lower group occupies the north-western shore of the lake, and sweeps round its extreme westerly end, but in the extension eastward of it and the upper group they are divided from the south shore by sandstones of a very different character to those which are interstratified with their own traps and conglomerates. These sandstones, which line the south shore, with but few interruptions, from Sault St. Marie to Duluth, lie in horizontal or very slightly inclined beds, and, being very friable, have been at several spots fashioned by the water into the fantastic forms known as the pictured rocks. Representatives of the same sandstone

* American Journal of Science, June, 1872.

occur on some of the islands along the north shore, being all that remains above water of the soft formation out of which the bed of the lake was hollowed. But while they yielded to the destructive agency of water, the harder beds of the copper-bearing groups have withstood them, and these, therefore, as on the point of the Keweenah promontory, rise abruptly out of the lake, which has washed away entirely the sandstone from their flanks, or, as towards the base of the promontory, spring at as abrupt an angle out of the horizontal sandstone strata, or else from islands, isolated or in groups, which, however, always bear a marked relation to one another and to the lines of upheaval distinguishable on the mainland.

The lower group of these rocks which we have described as confining the western end of the lake has not produced copper in workable quantities, and differs also in lithological character from the upper group. On the south side of the lake this upper group forms distinct ranges, the more easterly of which are traceable with remarkable parallelism from the base to the point of the Keweenah promontory; and they reappear on the north shore, the more westerly in Isle Royale, in the Thunder Bay and Neepigon promontories, and in the St. Ignace group of islands, the more easterly in Michipicotin and in some of the headlands of the coast.

The age of these rocks is the subject of some difference of opinion. They seem, from the observation of Brookes and Pompelly in Northern Michigan, to conform in strike and dip with the Huronian schists, both uniformly dipping to the north at angles of 50°—70°, and where the Huronian come in contact with the sandstones above mentioned, there is the same sudden alteration in dip as between these same sandstones and the copper-bearing rocks on the Keweenah promontory. Hence, one would infer that the traps and conglomerates of the upper bearing series come next in age to the underlying Huronian schists, and that subsequently to their upheaval were deposited the sandstones whose horizontality has not been broken by any disturbing force. The sandstones are generally attributed to the lower Silurian system.

Copper exploration on the Keweenah promontory have been made at innumerable spots over a distance of 100 miles along the strike of the beds, between the Point and Lake Agogibic, but the mines which have proved productive are confined to three districts, viz:, Keweenah Point or Eagle River, Portage Lake, and Ontonagon.

On the Point, the copper-bearing rocks attain their

greatest lateral development, and beds of conglomerate, melephyre, and compact sandstone, with the same dip and strike, stretch from shore to shore. Thence, as they curve round in a south-westerly direction, the range diminishes in width. Some of the first mines opened were on the west coast of the promontory, where, for nearly 30 miles, members of the copper-bearing series form the shore wall.

Here the most productive group of mines is on a system of fissure veins, which cut the rocks of the northern range at right angles to their strike. The Cliff Mine, the first of the lake mines to pay a dividend, and which, from first to last, has distributed nearly 2,280,000 dols. among its shareholders, is on a vein which, though not generally wide, was often filled with mass copper. The copper was associated with quartz, calc spar, and other vein stones. The contents of the fissure exhibited a banded structure, and was influenced markedly by the country rock. In this district, likewise, copper was mined from a bed of amygdaloidal trap, here known as the *ash bed*, and work was also done on conglomerate beds; but, if we except Copper Falls and the Phenix Mines, the operations on the fissure veins alone have been financially successful.

While the Cliff Mine near the point of the promontory was the first to prove that the native copper is more than a mineralogical curiosity, the Minnesota, near the south-western end of the range in the Ontanogan district, became even more famous from the enormous masses of copper it produced. Here, likewise, the copper occurs in veins which, though running with the strata, are palpably subsequent formations consisting chiefly of quartz, calc spar, and laumonite. The vein stone is different from the enclosing rock, the walls are well-defined and often grooved. In the Minnesota, the masses were not only large, but frequently threw off branches into the enclosing rock, which interfered with their being detached in the usual manner by removing the country rock adjacent. The prosperity of the mine ceased after the extraction of a mass of 90 per cent copper, weighing 525 tons, in 1857. No mines here are flourishing at present, nor does there seem to be a like revival of mining industry to what is taking place in the Keweenah Point district on the *ash bed*, under the infection of the successful development of certain beds near Portage Lake.

Portage Lake and River extend so nearly across the promontory at about 60 miles from its point that a canal less than three miles long suffices to give water communication between the east and west shores. The lake is

an irregularly-shaped body, as much as two miles wide where excavated out of the low-lying sandstone, but tapering rapidly where the high, bluff cliffs of the trap beds of the copper-bearing series confine it. While still in the low-lying horizontal sandstone, it throws off towards the north-east a long arm, which expands into Torch Lake, a considerable body of water whose north-west shore almost defines the line of contact between the horizontal sandstone and the steeply-tilted copper-bearing rocks.

As the steamer enters the narrows, and there come into view the towns of Hancock and Houghton facing one another on the opposite banks, the large mills on the lake shore, and the mine buildings and tramways on the heights above, the contrast between the modes of activity and the aims of civilised man, and of the Indians, with whom the traveller, if he has been long on the lake, must have come into close contact, strikes the mind very forcibly.

Where the copper-bearing rocks are exposed by the deep fissures, whose bottom is occupied by Portage Lake, the width of the range is seven miles, and the beds dip at an angle of 54° to the North West. They consist of traps of varying degrees of compactness and shades of colours, interstratified with conglomerates and sandstones.

According to Macfarlane, "the constituent of the traps of the Portage Lake District are principally felspar of the labradorite species, and chlorite of a species allied to delessite, with which are found occasionally mica, small quantities of magnetite, and perhaps of augite and hornblende."* He considers the characteristic trap of the region to consist of:—

Delessite	46·36
Labradorite	47·43
Pyroxene	5·26
Magnetite	0·45
	100·00

The mines in the immediate vicinity of the Lake are on the amygdaloidal trap. Many have been opened both on the north and south shores, but those only on the Pewabic lode—the Quincy, Pewabic, and Franklin mines—have returned profit to their shareholders. Of these three, the best worked, and therefore most successful, is and has been the Quincy, and we shall therefore describe it as being a typical, though the best example, of its class.

* Geological Survey of Canada, 1866, page 158.

It was opened in 1849, and has been worked uninterruptedly ever since, stemming the tide of low prices when almost every other mine was carried down the current.

The lowest level is at 1330 feet along the dip of the bed, and therefore on the incline of the shaft from surface, and the longest level is 1600 feet. The shafts and all the workings are opened in productive ground, where that can be followed; but as the walls of the copper-bearing bed are never well defined, and as tracts of rich ground abruptly alternate with stretches of barren rock, there is found considerable difficulty in keeping to the lode, as it is called. Moreover, from being pinched and poor, or even barren, it will suddenly bulge to 20 or 30 feet of rich rock. The hanging *wall* is composed of a fine-grained, compact, bluish trap, but the characteristic trap beneath is coarse-grained and amygdaloidal, and approaches in appearance to the copper-bearing rock.

The copper bed, however, while likewise generally permeated with small amygdules, is of a deeper red and breaks with a more uneven fracture. The minerals which fill the amygdules in the barren bed, viz. quartz, calcspar, lawmonite, prehnite, not only fill the amygdules here, but likewise form irregular veinlets rich in copper; and the chlorite constituents of the rock prevail so largely in parts as to give it a deep green shade. Pellicles of native copper enveloped in chlorite often occupy the centre of the amygdules. We see here the tendency of the copper to aggregate with the quartz, and the *same* zeolitic minerals as compose the fissure veins of the Eagle River, and the bedded veins of the Ontonagon districts; and, therefore, if we attribute the formation of the one to aqueous agencies, are led to ask whether the same agencies have not had more to do with the formation of the beds and their mineral contents than has generally been attributed to them.

Sheets of native copper occur between the joints of the trap in the copper bed, and formed evidently through infiltration, are found also between the trap blocks beyond the walls of the bed. An indication of subsequent aqueous action is seen in the streaks of clay which smear to a great depth the faces of the trap blocks. A single cross course, carrying quartz, but no copper, is said to have been met with. The width of the bed of copper-bearing ground is supposed to be about 70 feet; not that in any place 70 feet of productive rock has been found, but when copper has been lost on one wall, as much as 70 feet have been driven through what is supposed to be the same bed, and copper

found in what has been taken for the other wall. More than once, cross cuttings for many fathoms have thus resuscitated parts of the mine where it was feared the copper had given out altogether. The suddenness with which the rock will change and lose its metalliferous character is very remarkable, and affects, naturally, the productiveness of the mine from year to year.

Copper-bearing beds alternate, however, with barren trap for a distance of 500 feet, as determined by a cross cut eastward from the 70 fathoms level of the neighbouring Pewabic Mine. In the report of the agent of that mine, in 1863, he anticipates that the following copper beds would be reached at the distances indicated. The results justified his predictions. From the Pewabic lode, the distances of the adjacent strata were :—

As Anticipated.		As Determined.	
Old Pewabic . . .	148 feet.	Old Pewabic . . .	171 feet.
Green Amygdaloid .	285 ,,	Green Amygdaloid .	275 ,,
Albany and Boston .	382 ,,	Albany and Boston .	380 ,,
Epidote or Mesnard .	465 ,,	Epidote or Mesnard .	448 ,,
Conglomerate . . .	520 ,,	Conglomerate . . .	500 ,,

To the West of the Quincy and Pewabic lode, little mining has been done on the lake shore, the Hancock being the only copper-bearing bed extensively worked.

The heaviest copper lies generally near the foot wall. Throughout the region the metal is classed according to its size as mass, barrel, and stamp work. Mass copper is confined to the other districts; but the Quincy Mine yields a certain quantity of barrel work, or copper pieces of such size that they can be separated from adhering rock without the aid of water dressing. The quantity is, however, small, compared with that which is scattered in particles so small that machinery and mechanical concentration alone can separate them from their matrix. The means used to effect the separation are the same in all the mills of the district.

The equipment of the Quincy Mine above and below ground is excellent. The hoisting cars are of heavy boiler plate. Here and at other mines the cars discharge themselves by means of a very simple device. They are shaped like large coal-scuttles, and run on four wheels; but on the same axle, and projecting beyond the back wheels, are wheels of smaller diameter, which, when the car reaches the spot where it is to be emptied, run up inclines secured on each side beyond the track. Thus the back wheels are lifted off the track, while the four wheels remain on the rails and the body of the waggon, tilted forward, shoots out its contents.

Heretofore it has been the custom in the Portage Lake

shore mines to calcine the rock, and thus render it more friable; but following the example of the Calumet Mine, a hammer like a pile driver has been introduced into the Quincy ore-house, which reduces the larger blocks to a size suitable to the Blake crusher, and for hand-picking. The ore undergoes the following treatment. Discharged from the hoisting car, it is carried down an incline to the ore-house, which is on the brink of the steep hill overlooking the lake. The ore-house is provided with a hammer, under which, as stated, the largest blocks, weighing often over a ton, are broken. Such blocks require enormous force to shiver them, inasmuch as they are generally permeated with metallic copper in arborescent masses, which so binds the rock together, that even when broken, fresh force has to be used to drag the detached stones asunder. In the ore houses a preliminary hand sorting of the rock takes place before it is further reduced in size by Blake's crushers. Beneath the Blake crushers, other hand pickers are stationed, who separate still more of the barren or almost barren rock; and the ore, reduced in quantity to about two-fifths of what was hoisted out of the mine, is run down the steep inclined tramway to the copper house.

Stamps are used invariably throughout the peninsula for crushing the ore. Cornish rolls have been tried, but without benefit. They become so often clogged with the larger lumps of copper, and, thus kept apart, so much stuff passes through uncrushed, that the quantity of raff was enormous, and the yield of the rolls small. In the Quincy Mill, when running to its full capacity, 70 square shafted stamps, weighing 900 lbs. each, and with a drop of 16 inches, crush 232 short tons of rock, or 3·3 tons per stamp head per diem through screens perforated with $\frac{1}{4}$-inch holes. Two of the batteries are engaged upon the barrel work, which is, by their pounding action, more perfectly freed from rock than it can be in the ore-house, but has, of course, to be removed from the battery-box; and all the battery-boxes have to be cleaned out twice a day. From the batteries the ore passes on to shaking sieves perforated with $\frac{1}{8}$-inch holes, and fine and coarse are further classified before being concentrated by entering with a full stream of water a succession of long triangular troughs which diminish in diameter and depth as size after size is drawn off to its proper hutch. The hutches everywhere used are piston hutches with fixed bottoms; and though in different mills they go under different names, the differences are in reality trifling. Collom's jigs are those most commonly used, and consist of a central piston-

box divided into two compartments, each of which is in communication with an adjacent compartment in which the sieve is fixed and into which the copper that passes through the sieve falls. The pistons of the two hutches are pressed down by a single rock shaft, and each piston is lifted back into position by a spring—a desirable motion—as the down-stroke is thus sharp and rapid, and the up-stroke slower. But the hutch is open to the objection that, as each piston covers only half the corresponding sieve, a wave is propagated from one end of the sieve to the other, which interferes with the regular subsidence of the ore. As the ore is imperfectly sized, some collects in the sieve and is removed from time to time, but most falls into the bottom, whence it is carried away by the flow of water.

The hutches are arranged, with a view to saving labour, in tiers one below the other, so that the scimpings from one flow into a hutch on a tier below, and the concentrate is re-concentrated in like manner. Water being the carrier, no handling, or very little, is required from the time the ore is thrown into the stamps till it is shovelled from the receiving tank as 80 to 90 per cent copper.

One of the most perfect mills on the lake shore is that of the old South Pewabic mine—now the Atlantic. In it, the stuff crushed by Ball's stamps is concentrated by 112 hutches arranged in seven tiers. There, also, the rotating German buddle is found to save the copper from the slimes effectually and cheaply. In the Quincy Mill, the old-fashioned percussion-table takes out the coarse slimes, and tributers re-treat the refuse from the whole mill in a separate building with English buddles. The coarse concentrate generally runs to nearly 90 per cent of copper, the fine, which cannot be separated, without repeated washing, from the iron—which we have seen is a constituent of the trap matrix—sometimes stands as low as 50 per cent; but all the mills aim at delivering an average of 80 per cent to the smelting works.

Side by side with the Quincy Mill is the Pewabic Mill, in which Ball's stamps are used. A comparison of the tailings from the two mills, made by Mr. Macfarlane, is interesting. He found—

Quincy Mill.		Pewabic Mill.	
Scimpings from coarse ragging	0·06 per cent.	From head of run	4·93 per cent.
Scimpings from fine ragging	0·73 „	„ middle of run	3·00 „
Buddle tailings	0·46 „	„ end of run	3·13 „
		„ heap outside of run-house.	0·66 „
		„ sand bank	1·00 „

The Ball stamps may influence the result, through the volume of water required for their efficient working, and which, not being separated from the suspended ore, may in some cases flood the hutches.

The annual reports of the Quincy Mining Company are models, presenting the work done and the cost of doing it in clearest detail. From the report for 1872 we summarise the following particulars. During the year, there were stoped 5165 fathoms, and sunk in shafts and winzes 898 feet —say 150 fathoms, and driven 1974 feet—say 329 fathoms. Assuming the specific gravity of the rock to be 2·7, and that therefore there are 18 tons to the cubic fathom, there were broken 101,592 tons of rock. As there were 60,828 tons stamped, about 4-10ths of the rock was separated by hand-picking. The mining, raising, and picking cost for the year amounted to 283,487·30 dols., or 2·79 dols. per ton of rock raised, while the milling cost was 64,783·79 dols., or 1·06 dols. per ton of rock stamped. This large amount of rock yielded 2,804,954 lbs. of concentrated mineral, which produced 2,276,308 lbs. of ingot. There was recovered, therefore, only 1·12 per cent of copper from the rock mined, and yet there were divided, as the year's profits on working, 210,090 dols.

In 1872, copper brought an exceptionally good price, selling at 32½ cents per lb., but as a set-off, wages were high, the average wage of miners on contract being 60·62 dols., and the yield of the ground per fathom lower than its wont.

Distributing the cost over the mineral produced, we find that, as 2,804,954 lbs. of mineral—which, without making an allowance for the slight loss in smelting, must have contained 81·1 per cent of copper—were obtained at a cost for mining and concentrating of 461,147·83 dols., each pound cost 16·44 cents; but when the cost of smelting, transport, insurance, and commission was added, each pound of ingot cost 22·93 cents U. S. currency, or, say, 20 cents in gold. Copper has fallen to 25 cents U. S. currency, but as wages have declined proportionately, and the cost of production therefore has been lessened, there is not likely to be a very serious decrease in the profits. Besides distributing this large sum among the shareholders, there were added to construction account,—for permanent improvements likely to lessen the cost of future production,—67,227·65 dols., so that the real profits of the year were 277,318·35 dols., which certainly could have been realised only by good management and by the employment of every possible labour-

saving appliance for the working of an ore yielding but 1·1 per cent of copper.

Another mine even more interesting to the mineralogist, and more startling in its yield, is the Calumet and Hecla. It is situated 13 miles from Portage Lake, in a north-east direction, on a bed of conglomerate, which, however, it is not easy to identify with any of the beds that abut on the lake, as the range widens as it approaches the Point and the beds flatten. While the mineral range at the lake is 7 miles across, at the Calumet and Hecla it is 13 miles wide, and the dip declines from an average angle of 54° to 38°. Copper had been extracted from conglomerate beds before the opening of this mine, but never with good financial results. From the Albany and Boston Mine, where both a conglomerate and an amygdaloidal bed are worked, specimens very similar to the rock since yielded by Calumet were obtained; but the failure of this and other mines led to a distrust in, and a too hasty condemnation of, conglomerate mines. It is to be feared the opposite error may now be run into.

The Calumet Mine was discovered about 13 years ago. An inn, the half-way house between Hancock and Eagle River, stood in the forest near where the mine is now, and was kept by a Cornish man. His pig—so tradition tells—fell into a pit, which proved to be an old Indian working. It was dragged out so be-smeared with green that the owner at once suspected the existence of copper. Since then, two little towns,—Calumet and Red Jacket,—have sprung up, and as great a change has taken place beneath the surface of the soil. Two mines on adjacent locations, though in the same bed, viz., the Calumet and Hecla, are owned and worked by one company. This mine has now reached a depth of 1060 feet on the incline of the bed, or 600 feet vertical, and one of the upper levels is 3000 feet long. Most of the copper comes from a bed of conglomerate, in which a hard red porphyritic pebble is embedded in a cement of the same rock, and of native copper. The pebbles in the rich rock are smaller and more rounded than beyond the rich chimnies. The pebbles composing the conglomerate are seldom themselves cupriferous, though some of them are. I have a large pebble from the conglomerate bed which is identical in appearance with the compact chocolate-coloured rock of the Quincy Mine, and is throughout permeated with a little copper in the same manner as the rock, but for a depth of about two lines from the surface it is ensheathed in fine-grained copper, which, as well as the

copper permeating it, may have penetrated the pebble or been deposited around it,—it is difficult to say which. In the conglomerate also occur boulders of solid copper. Some are said to exhibit a concentric arrangement of the copper, but one I had cut through the centre was homogeneous in structure, but contained, embedded in the copper, a few crystals of quartz and felspar.

Interstratified with the conglomerate are thin bands of copper sandstone, the copper being in fine grains, sometimes deposited pure, at others mixed with epidote and quartz or finely-ground porphyry, the laminæ easily separable from one another. In their midst are sometimes embedded pebbles of copper. Bands of hard compact sandstone, from the disintegration of the same rock as compose the conglomerate, are met with beneath the foot wall, on the hanging wall, or in the bed itself. A specimen in my possession exhibits successive layers firmly compacted, some of conglomerate, others of coarse-grained and others of fine-grained sandstone, with a surface distinctly ripple-marked. The aqueous origin of the bed cannot be doubted, but whether the copper was mechanically or chemically deposited, it is more difficult to decide. The easier explanation of its occurrence is on the hypothesis of a mechanical deposition, but, as militating strongly against it, is the undoubted fact that the conglomerate pebbles very rarely carry copper. The effects of subsequent chemical action are beautifully exhibited in a clay *fluccan* which, from the surface to nearly the lowest level driven, lines in places the foot-wall. In it, embedded in soft clay, derived from the disintegration of the rock, and which harden into a mass that might almost be mistaken for a piece of trap, occur with calc spar, laumonite, and quartz, copper in dendritic masses, distinctly crystallised. Some of the specimens taken from the fluccan undoubtedly exhibit instances of false crystallisation, plainly showing the impress of the crystals amidst which they were formed, but others are as undoubtedly themselves crystallised. *Vugs* also occur lined with crystals of epidote, and calc spar, and spongy copper; and through the bed there passes diagonally what is called a dropper. It is only a few inches wide, but consists of what is locally called brick copper, which is accompanied by crystallised silicated minerals, entangled in which are conglomerate pebbles. It has unmistakable *slickensides*, on which the copper is actually polished.

A bed of amygdaloidal trap overlies the conglomerate, and is in places rich in copper. Some of the amygdules are

completely filled with copper, in others a small nucleus of copper is enveloped in calc spar or epidote, while a coating of red ferruginous-looking earth lines the cell. A trap, similar in appearance, is worked by the South Pewabic Mine on Portage Lake, but there its richness is deceptive, for the copper forms in this shell only around an earthy nucleus.

The long levels of the Calumet and Hecla run through three rich chimnies of conglomerate, the longest about 1300 feet. They dip to the north, and are widening out rather than otherwise in its lower levels. Between these rich streaks, large tracts of which will yield a 20 per cent ore, are others of poorer ground, and others still almost barren, which are left standing. The average width of the productive portions is 13 feet.

There are broken, raised, and concentrated, 740 tons of rock a day. To handle such a large quantity, work has necessarily to be thoroughly systematised both below and above ground, and machinery utilised to the utmost.

Each mine possesses six shafts,—or twelve in all,—eight only of which are connected by levels, and four only used as hauling shafts. The shafts are sunk at 400 feet apart, and levels are driven every 90 feet. Between each two shafts two winzes are sunk, and three stopes 30 feet high are opened on each side of each winze, so that eighteen stopes are worked between each two shafts. Six feet of ground are left standing on each side the shafts, and a heavy arch below each level supports the roof, and gives firm foundation to the road-way. A wall of heavy stulls provided with gates at every 10 feet protect the road-ways, and allow large accumulations to be made in the stopes. Timbering is a heavy item of expense, as the trap which composes the roof is very liable to fall out in pyramidal blocks. The mine-work is done by contract,—stoping by the fathom, drifting and sinking by the foot. The contractor must deliver his rock at the nearest hauling-shaft. The traps are 4 feet apart in the levels, and 4 feet 4 inches in the shafts, as the cars have to be large to receive the heavy blocks which break away in the stopes. The miners are allowed to send to the surface blocks not over 1 ton weight, but the cars are constructed to hold 2 tons.

Drifting is done with great economy, by machine-drilling. Seven Burleigh drills of large size, with 2-inch bits, are steadily at work in each mine, and it is found that with them a drift 10 feet wide can be driven at 8·00 dols. less per foot than a 6-foot drift by hand-labour. This calculation

leaves out, however, the cost of the motor power. In the Quincy Mine, the same drills are being thrown aside as uneconomical,—a discrepancy in result which may be accounted for by the fact that in the Calumet there is a well-defined salvage, whereas in the Quincy the drifts are run through solid rock, and grooves must be scooped out beneath the face of this advancing drift,—an operation not easily performed with a cumbrous drill.

The ore is broken in two ore-houses, each of which is provided with a pile driver to shatter the large masses—a Blake's crusher with 18 by 24 inch opening, and six smaller Blakes, with 8 by 15 inch openings, but no attempt is made at selecting by hand, but all the ore raised passes to the mill.

From the crushers the ore falls into huge hoppers, whence it is discharged as called for into the railway cars. All the appliances, in fact, are on a scale such as we are in the habit of associating with iron mining. A five-mile railroad unites the concentrating works on Torch Lake with the mine, and over it two hundred car-loads of 4-ton capacity each are carried daily.

The mills present no feature of special interest. In one are three of Ball's stamps, and in the other four. Six of these powerful machines are running regularly, and crush up the whole yield of the mines. To each stamp there are assigned 20 jigs.

The stamps are steam-hammers. The slide valve is worked by eccentric gearing, and the piston-rod is inserted into the head of the shaft, which is 9 inches in diameter. The stamp-head is 22 by 14 inches, and weighs 6 cwts. Its upper surface is provided with a bevelled ridge, which slides into a slot in the bottom of the shaft, and is then keyed home. When working on the amygdaloidal trap, Ball's stamp heads, made with white iron and a small percentage of Franklinite and tough pig, last a month. At the Calumet Mills they are worn out in six days, but the renewal involves a stopping of the stamp of only 50 minutes. Each stamp works in a separate stamp-box, which is five-sided, and discharges from three sides through steel plates, perforated with 3-16th inch holes. Each stamp can crush daily 120 tons of this exceedingly hard rock, and is said to consume 25 horse-power; 3000 gallons of water a minute are pumped to the two mills. The great advantages of using the stamp are that so much work can be done with so little machinery and in so contracted a space, and that so little time is occupied in repairs. The Calumet Mills never stop. The Quincy mill is idle for about one month out of twelve.

The scimpings are not clean. They carry from 1·40 per cent. to 1·80 per cent of copper, 0·40 to 0·80 of which is as oxide. Twelve tons of copper, therefore, are thrown away daily.

The Calumet Company publishes no report, but the following figures are, if not quite, very nearly correct. There are 1600 hands employed, 260 contracts are set in the Calumet, and a somewhat greater number in the Hecla. The cost of breaking a fathom of ground varies from 20·00 to 22·00 dols., and it yields 21 tons of rock; the cost of dressing exceeds that at the Quincy mine, standing at 1·17 dols. per ton. In 1872 the mine produced 9717 tons of ingot. The quantity of ore raised daily was about 740 tons, or 266,400 tons per year of 360 days; and, therefore, as it produced 9717 tons of ingot, the ore actually yielded 3·6 per cent of copper. This large amount of work was rewarded by profit in proportion; for there was distributed among the shareholders, in 1872, 2,750,000 dols.; and during that same year large sums were expended in permanent improvements. The result in every respect is unparalleled in the history of copper mining; and all owners of copper mines with no such brilliant promise can only hope that it may not be repeated; for the effect of a very few such mines would be most depressing.

Adjoining the Hecla another mine is being opened by the Osceola Mining Company, which, from surface indications, will be very rich. The Allonez near by is expected to turn out well, and on the Isle Royale attention is again being given to long-neglected conglomerate beds, and the prospect of success is there good also. The Royale, though belonging to Michigan, lies close to the Canadian shore. As already pointed out, the copper formation is largely developed from Michipicoten to Thunder Bay on the main land and on Canadian Islands.

With the experience gained on the south shore, explorations could now be conducted on the north, with better chance of success than heretofore. What little has been done has revealed the existence of deposits that would not have remained unworked had they been situated on the opposite shore.

The following statistics, officially correct, are taken from the annual circulars published by the "Portage Lake Mining Gazette."

The production of all the mines on the promontory for the year ending Nov. 30, 1873, was as follows:—

	Tons.	Pounds.
Calumet and Hecla, for year ending Nov. 30, 1873	11,551	1,938
Quincy, for year ending Nov. 30, 1873	1,680	180
Franklin Pewabic	671	1,673
Houghton	285	—
Schoolcraft	270	1,520
Concord	72	—
Isle Royale	143	1,417
Atlantic, for broken season	464	701
Albany and Boston, broken season	50	—
Sumner, for year ending with close of navigation	77	—
Other sources	8	—
Total	15,194	1,429
Production in 1872	12,612	319
Increase in 1873	2,582	1,110

Keweenah Point District.

Central, for year ending Nov. 30, 1873	1,081	1,983
Copper Falls, for year ending with close of navigation	834	927
Phenix	350	—
Cuff	279	1,264
Delaware, for year ending Nov. 18, 1873	55	742
Amygdaloid, broken season	19	303
Other sources	2	184
Total	2,781	1,903
Product in 1872	1,836	894
Increase in 1873	945	1,009

Ontonagon District.

	Tons.	Pounds.		Tons.	Pounds.
Ridge	150	113	Knowlton	39	1,864
National	131	318	Rockland	16	460
Minnesota.	103	1,700	Mass	6	868
Flint Steel	45	1,356	Adventure	3	1,238
Bohemian	40	500	Tremont	—	700
Total				537	1,117
Product in 1872				725	1,000
Decrease in 1873				187	1,883

Recapitulation.

	Tons.	Pounds.
Portage Lake District.	15,194	1,429
Keweenah Point District	2,781	1,903
Ontonagon District	537	1,117
Grand total for 1873	18,514	4,449
Or about	14,811	tons of ingot.

The Copper Mineral (of about 80 per cent), produced from 1845 to 1874.

	Tons.
1845 to 1854	7,642
1854 to 1858	11,312
1858	4,100
1859	4,200
1860	6,000
1861	7,500
1862	9,962
1863	8,548
1864	8,472
1865	10,791
1866	10,376
1867	11,735
1868	13,049
1869	15,288
1870	16,183
1871	16,071
1872	15,166
1873	18,514
Total . . .	194,909

About 150,575 tons ingots; value about 82,000,000 dols.

In 1872 there were distributed in dividends—

	Dollars.
Calumet and Hecla . . .	2,750,000
Quincy	350,000
Pittsburgh and Boston (Cliff)	100,000
Central	80,000
Minnesota	50,000
Franklin	20,000
Pewabic	20,000
National	20,000
Total dividends . . .	3,390,000
Total assessments . .	190,000
Excess of dividends over assessments,	3,200,000

The same mines have been remunerative from their openings, and have yielded 11,810,000 dols.

The paid-up capital on the same mines amounts to the trifling sum—

	Dollars.
Calumet and Hecla . . .	800,000
Quincy	200,000
Pittsburgh and Boston . .	110,000
Central	100,000
Minnesota	436,000
Franklin	370,000
Pewabic	235,000
National	110,000
	2,361,000
Increase of dividend over assessments,	9,449,000

There is, of course, another side to the picture. Of 111 mining companies formed, only the eight above enumerated and the Copper Falls Company have paid dividends. Many of the companies were organised to work locations where there was no copper at all, and others failed through ignorance and bad management. The total amount levied, as far as can be ascertained, has been 19,296,500 dols.

All the copper produced in the Peninsula is smelted at Hancock on Portage Lake, or at Detroit, branches of the same establishment. Detroit takes the mass copper from the Keweenah and Ontonagon Districts, as the furnaces there are constructed to receive it. The roof of the reverberatories are lifted, and masses of 10 tons lowered on to the bed, when the roof is replaced, luted down, and the fires lighted. In the Hancock establishment only the barrel and stamp work of the Portage District is treated.

The mineral from each mine is smelted apart, and the copper returned in ingots; 18·00 dols. per ton being charged for the first smelting, and 12·00 dols. for every ton of slag and coarse copper re-smelted.

In the Hancock establishment there are seven reverberatories and two cupola furnaces.

The copper is smelted without any flux in the reverberatories, in charges of 16 tons. Eight to ten hours are occupied in running down, two to three hours in poling, and three hours in ladling out. When pressed for time nine charges are smelted a week.

The product is about 78 per cent of the copper as ingot, a rich slag which is returned to the reverberatory, and a

poorer slag which is re-smelted in Mackenzie's blast-furnace with lime as a flux. The valuable product from the cupola is a coarse copper of 85 per cent, which is treated in the same manner as the crude mineral, and a poor slag carrying not over 3-10ths per cent of copper.

One thousand pounds of coal are said to be consumed in the reverberatories to every 2000 lbs. of mineral smelted. Poling is done with birch rods. At Detroit, when poplar could no longer be obtained, oak was substituted without affecting the toughness of the metal.

IV. ON THE MODERN HYPOTHESES OF ATOMIC MATTER AND LUMINIFEROUS ETHER.

By Henry Deacon.

THE generally received opinion as to the constitution of the material universe can be summarised pretty accurately by saying that all natural objects consist of either atoms, which are solid centres of force or of motion,—or of ether, the medium through which the forces or motions of atoms are transmitted,—or of both atoms and ether.

A molecule is defined as the smallest piece of any substance that can retain all the properties of the substance, and therefore the constitutions of the molecule and of the substance are identical.

The different qualities ascribed to atoms and to ether are best reviewed by parallel comparison, of which the following is an illustration :—

Atoms are inelastic.	Ether is perfectly elastic.
Atoms are indivisible.	Ether is infinitely divisible.
Atoms do not touch, or atomic matter is not continuous in all directions.	Ether is continuous.
Atoms coalescing evolve energy, and in separating absorb energy.	Ether coalesces, and is divided without evolving or absorbing energy.
Atoms gravitate.	Ether does not gravitate.
Atoms possess "mass" and inertia, and in motion momentum.	Ether has neither "mass" nor inertia, and cannot be imbued with momentum.
Atoms originate and transmute or convert motion and force.	Ether is merely a medium, and can only transmit motion or force unchanged.
Atoms, being inelastic, move as a whole instantaneously, *i.e.*, motion passes through or is imparted to the whole of an atom, or continuous atoms, without any lapse of time.	Ether is moved by degrees, and time elapses as motion passes through or is imparted to it.

That these converse qualities are necessary corollaries, one of another, will be evident on a brief examination; and whilst incidentally showing this connection, I would criticise those hypotheses which deny the quality of elasticity to tangible matter apparently possessing it, and which simultaneously create a new and totally different kind of matter to receive it.

Atoms are described as swinging to and fro in this wonderful ether, without loss of motion or of energy, and they consequently either impart no motion to ether, or else motion must be communicable to it without absorption of energy. But ether is a medium that transmits motion, or its necessity and office disappear. If atoms do move ether, and any energy be absorbed, the motion which is the energy possessed by the atoms must decrease. If no energy be absorbed, and yet ether be moved, then either ether movements are arrested without result or energy must be created. An alternative is a possibility, viz., all kinds of motion may be imparted to atoms, but only some kinds of motion to ether.

The question then arises—Is it not easier to make atoms elastic and matter continuous, and so altogether avoid the necessity for ether? And before admitting the necessity for the existence of ether, it will be well to review the known properties of matter, and philosophically safer to imagine their extension in the same direction, even to an indefinitely great degree, than to imagine the existence of matter of an entirely different and unknown kind.

Atomic matter forms an indefinitely small bulk in the universe. We see the sun, moon, and stars, and all the host of heaven, but when we calculate their dimensions and distances, and compare the bulk of these bodies with the bulk of the sphere of ether containing them, and by whose aid we know them, figures fail to convey any idea of the indefinitely small bulk of matter compared with the indefinitely enormous bulk of ether.

Taking the distance of the sun from the nearest fixed star (*a* in Centaur) as the radius of a sphere of ether, and comparing its bulk with the bulk of our solar system, as being the smallest possible proportion in which atomic matter and ether can exist, it is as 11,000 trillions to 1—a proportion comparable, perhaps, to a needle weighing 1 grain in a bundle of 600,000 million tons of hay, and the true proportion of ether to atomic matter must be indefinitely greater than this. It puts this question in a somewhat different light to reflect that the unique and positive qualities

of the mass of matter in the universe are, by inference, without proof, held to differ in essence from the observed qualities of an indefinitely small fraction of the mass, and that fraction a totally different kind of matter.

It is a disruption of the idea of continuity, and of the unity of creation, to assume that the larger and unknown quantity of matter differs totally from that which is known. The proposition that we judge of the unknown by the known implies that the unknown resembles the known, or it cannot be appreciated; and in this sense scientific method requires that the unknown properties of ether should be proved, for they do not resemble any of the known properties of matter.

The admitted want is a medium for conveying force, or, in other words, motion of all kinds; and if we ascertain in what way force or motion is most probably conveyed in known instances, we shall then know more of the probably necessary qualities of the required medium.

Grove's experiment of a silver gridiron on a daguerreotype plate, placed in the sunlight and connected with a galvanometer, proves that the sun's rays are converted into chemical action on the plate, electricity through the wires, magnetism in the coil, sensible heat in the helix, and motion in the needle, exhausting all the forces in the sun's visible rays, so far as known. These forces must all have some property in common, as they are mutually convertible, and that property is motion.

All natural motion is, or becomes, rhythmical. No instance occurs to me either of natural uniform motion, or of motion in a straight line or in a circle. The path of the planets, as regards the sun, are elliptical, and their motions accelerate and retard; and as regards space, their paths are still more complicated. Hence the medium we require to transmit force must transmit vibratory motion.

Vibratory motion is of two kinds, or may be resolved into two kinds, viz., vibration across the line of progression, like all the vibrations or forces accompanying light and the waves of the sea; and vibratory in the line of progression, to and fro, like the waves of sound.

The action or force called gravitation is a special property of atomic matter; on it all the properties of mechanical "mass" depend.

Many of the concrete arguments as to the conservation of force turn on the "mass" of matter remaining unchanged under all circumstances: relative unalterability of "mass" is the chemist's absolute creed.

Gravitation is called attraction—"The sun attracts the earth." Attraction, as the name of the phenomenon, is free from objection; but if attraction be a quality, it is the same in kind as suction, and suction we know is the name —and not the explanation—of phenomena. That one atom or mass of atoms can resist and push, and so impart motion to another, is comprehensible; but that one atom or mass should at a distance attract or suck another towards it is incomprehensible. The fact of the approach is seen, and is called attraction, but the reasons for it have to be sought.

Prof. Guthrie, in 1869, communicated to the Royal Society some experimental results, which assist the comprehension of attraction. He found that a sounding tuning-fork attracted such things as the smoke of a candle and delicately suspended pieces of paper. Due precautions were taken to show this attraction was the result only of the vibration, and not of electricity or currents of air, &c. A tambourine strongly vibrated, and other vibratory surfaces, give more powerful manifestations.

In 1870 Sir W. Thomson pointed out that these results were in accordance with general mathematical laws, applicable to all elastic fluids whose particles were put in motion by immersed bodies, either vibrating to and fro, or whirling about in any way. In Guthrie's experiments the vibrations were those of sound, which act to and fro in the line of progression.

In the sunbeam there are both visible and invisible rays, but all those rays obey strictly similar laws, as to speed, reflection, refraction, and polarisation, and hence must be motions of the same kind, and, like light, are vibrations across the line of progression.

"The sun attracts the earth," and gravity acts when the sun's light is absent; hence the lines or rays of the force of gravity are independent of the sunbeam, and probably follow different laws.

So far as attraction is concerned, Guthrie has shown that to-and-fro vibratory motion suffices, and, as all known effects of gravity can be shown to follow from attraction, gravity itself may be the effect of to-and-fro vibrations. It is necessary, moreover, that these vibrations be such as the vibrations of light, &c., do not affect.

Mechanically, all motions that are at right angles to each other proceed without what is technically known as "interference," or, so to say, proceed uninterruptedly. A cannon, whose axis is parallel to the horizon, may project balls with very small and with very great velocities, but each ball will

touch the same horizontal and lower plane at the same time, that time being the same as would be occupied by the fall of a ball in a vertical line from the cannon's mouth to the same horizontal plane. To-and-fro vibrations would, in this sense, be unaffected by transverse vibrations which are at right angles, and thus to-and-fro vibrations of gravity would be unaffected by the transverse vibrations of light, &c. Gravitation vibrations, if ultimately passing into space, would cause a body to lose weight.

It is supposed that suns and planets lose heat from the motion they impart to the rays or vibrations of radiant heat, but the effects of the sun's and planets' loss of heat are not now astronomically observable, and the effects of the loss of gravity and of heat may perhaps be observed simultaneously. As, however, gravity and heat rays are not of the same kind, there is probably a difference in the rate of their dissipation, and the force of gravity may be the weakest but most enduring. In the sunbeam there are both light and heat rays whose vibrations are of the same kind. Incandescent bodies yield similar duplex rays, but their radiant light is extinguished before their radiant heat; and we may conclude that if the sun's condition changes it will be dark long before it be cold; and as similar vibrations are found to dissipate energy, at different rates, dissimilar vibrations most probably follow the same rule.

According to the axiom of the conservation of energy, the rule as to its dissipation is, that energy is parted with or absorbed by work done. A feeble force, or one able to perform little work, absorbs only feeble energy to originate; conversely, a powerful force owes its origin to much energy, and the most powerful force may be the first dissipated.

In calling gravity a feeble force, the necessity of measuring a force becomes apparent. Light, heat, electricity, &c., are termed imponderable forces. This phrase, by implication, admits the possibility of ponderable forces. Is oxygen, for example, a ponderable force? An examination of this question will serve to show the sense in which these terms should be used. Assume oxygen to be a ponderable force, and it is at present impossible to refute the assumption by experiment. Andrews compressed oxygen to about the density of water, and it remained then, as ever, invisible and intangible, except by its forces, its ponderability included. Elements unite with oxygen, and fresh substances of different properties are produced. Heat unites with or is absorbed by ice, and water is produced. The allotropic forms of phosphorus and of sulphur, and many other

instances, will occur to every reader's mind where a substance of different properties is produced by the action or absorption of an imponderable force. A ponderable force would only add weight. If ice became heavier in melting we should say matter was added to it, only because it increased in weight. Radiant heat adds volume as well as sensible heat to the body that absorbs it, so that the addition of two qualities to a substance by the action of one force is not rare. Hence, in the attempt to prove that gravity is a feeble force, the difficulties of measuring forces by gravity, and of the conception of forces as apart from matter, must be remembered.

In many respects gravity well deserves to be called a feeble force. Our atmosphere sustains a load of 15 lbs. to the square inch; we call it a great load,—*i. e.*, a great result of gravity,—but do not equally appreciate the effort of the air in resisting it; it requires an intellectual effort to say the two are equal, and then the magnitude of this effort of gravity does not seem comparatively large.

Prof. Osborne Reynolds has recently shown that a small glass tube, sufficiently strong to be safely used as a gun, with gunpowder, so as to propel little brass rods through a half-inch board, was shattered into the minutest dust when partly filled with water and a charge of electricity discharged through it. A similar result, if obtained by gravity, would have required the pressure of a weight to be measured by many tons on the square inch. This experiment was made to illustrate the effect of lightning upon splitting trees, shattering stones, &c., and Faraday showed some years ago that more electricity was concerned in a dew-drop than ever was manifested in a thunderstorm. Many trees and stones are often shivered to fragments by one storm, showing that an equivalent to enormous mechanical or gravitation forces is latent in a part of one of the forces that builds up a drop of water.

Heat expands bodies, and requires an enormous mechanical or gravitation force to resist it. The rays of the sunbeam, if converted into mechanical force, would far exceed anything we can realise; and heat may be said to act paradoxically. Its absorption develops mechanical force, and so does its subtraction from freezing water and from solidifying bismuth.

The sunbeam also contains actinic or chemical rays, probably the most energetic of all, and for the mechanical equivalent of chemical energy we may again go to Faraday for an illustration.

XUM

The metal potassium, like other metals, is mechanically compressible only to a very limited extent: probably no means are known by which so great a weight or pressure could be applied as to compress, say, 450 units of it into the bulk originally filled by 400 units. Faraday points out that a space originally filled by 430 units of the pure metal potassium, if filled by the same potassium when by chemical action made into carbonate of potash, would then contain 686 instead of 430 units of the same metal, and, in addition, 2744 units of oxygen and carbon. He shows that this power of compression is not restricted to carbonate of potash, nor to potassium, but is even more strikingly exemplified when some other substances enter into chemical combination. No other force measured by gravity gives parallel manifestations.

Comparing the mechanical equivalent of gravity with the same equivalent of other forces, gravity is thus proved to be feeble, and, requiring little effort to originate it; it yields small effects, and is the more likely to be very slowly dissipated.

Perhaps an objection may be made that, although astronomically we see no effects of the loss of heat in the sun and planets, yet we see a hot body loses heat on the earth, but do not see it loses any weight whatever.

The hot body is noticeable because it is hotter than its surroundings. It only loses the excess of heat it had, and becomes cooler than the earth only when its surroundings are exceptional, and are, so to say, means through which its heat energy escapes, and it remains of the same heat as the earth, when subjected to the same conditions. Heat is a mode of motion; communicated heat is communicated motion; by substituting gravity for heat we can say gravity is a mode of motion, and communicated gravity is communicated motion. All substances are influenced by the motion of heat: analogically, all substances are influenced by the motion of gravity. The earth's heat maintains the heat in its parts, and the action is reciprocal; so, too, the gravity of the earth and its parts are reciprocal, and similarly of all related gravitating bodies, and hence no loss of gravity is apparent.

Mr. Crookes's recent experiments on the weight of bodies *in vacuo* prove that heat and gravity have *some* connection, and motions at right angles to each other do influence one another, although each passes on distinctly. One of the cannon-balls before alluded to moves in a path which is neither wholly vertical nor horizontal, although the vertical and horizontal planes it passes through are those through which each force alone would have sent it in the same order

in the same times. Vibrations at right angles may therefore have some connection, as on the principle of the well-known parallelogram of forces.

All radiating vibrations which absorb energy in their beginning, and evolve it when they are arrested, necessarily follow the same law, of effects lessening in proportion to the square of the distance from the centre of radiation. The effects of gravity are therefore consistent with its being a force due to radiant vibration.

Before quitting this point of the question, the velocities at which vibrations are known to be transmitted through matter require some notice. The ordinary surface-wave on water (a vibration across the line of progression) moves with a velocity of about 1 foot per second. The waves of light, vibrations of the same kind, pass through water with a velocity probably as correctly represented by 200,000 miles a second. And electricity passes through some metals still more rapidly. The waves of sound (to-and-fro vibrations in the line of progression) pass through water with a velocity of about 4000 feet per second. As there are certainly two varieties of transverse vibrations, there may be at least two varieties of to-and-fro vibrations, and, if so, the velocities of the varieties of each kind may bear the same or similar proportion to each other, and the velocity of transmission of the vibrations of gravity may probably be at least 4000 times as rapid as those of light.

The medium between atoms has to serve for the phenomena belonging to latent or potential energy, or the energy of position. This energy is of two kinds: one as when a weight is raised; the other kind such as a coiled or bent spring possesses.

The sunbeam reaches us, say, eight minutes after it left the sun. The waves of light present to us at any instant are so disconnected with others before and after them that both or either might be arrested without our immediate knowledge. In fact, as the earth sweeps on its course it cuts into fresh lines of waves, and leaves broken lines to continue their course. Each spot on the earth receives part only of one of the lines of waves of light reaching from the sun, and a still smaller proportion of the lines of those waves whose sources are the sun's we call fixed stars. A floating straw is moved on a pond's surface by the waves proceeding from a stone, which fell at a distance, some time before; and, although the spot where the stone fell is still, the straw moves.

All radiated vibrations follow the same rule, and "energy

of position" is due to the fact that the body, in moving, will receive, from the then existent vibrations, an energy the exact equivalent of the vibrations arrested, and probably, but not necessarily, the equivalent of the energy absorbed in placing it in position.

That energy of position is really due to the circumstances surrounding the position, from time to time, is perhaps still more evident from considering the difference in weight of the same body at the earth's poles and equator, 194 lbs. in the former position weighing only 193 in the latter one. But one of the clearest proofs is that of an electro-magnet and an iron bar. For convenience we may imagine the magnet placed vertically, and the iron bar upon it. The bar, being raised, acquires an energy of position due both to the magnetic attraction and force of gravity. It absorbs energy to raise it, and evolves its equivalent in its descent. But it may be raised whilst the electric current is stopped, and fall whilst it is passing. It would then evolve more energy in falling than was employed in raising it. *Vice versâ* if raised whilst the current passes, and falling when it is stopped; and, evidently too, variations in the electric current would vary either the energy required to raise the bar to any given position, or the energy of position after the bar is raised. Briefly, then, energy of position of this kind is in every case dependent on the forces or motion of the present, and is disconnected from the forces, or motion, or energy of the past; in its nature it is variable and accidental.

But latent or potential energy of another kind may and probably does exist, viz., the latent energy of a bent spring; but this raises the question of elasticity as a quality of tangible matter, and it is difficult or impossible to comprehend the possibility of this form of energy, except the quality of elasticity be assumed. A compressed gas on the atomic hypothesis is elastic because the paths of its atoms are shortened, and their impacts more frequent; it is not a quality of the gas, but of its mechanical structure, and is dependent on the motion of its particles. But on appealing to experimental results, we find when any tangible substance is broken up the transmission of vibration is interrupted. Beginning with a cracked bell, we may pass to Tyndall's recent proof that alternate layers of gas of different densities retard sound, and twenty-five alternate layers of coal gas and carbonic acid gas, forming a column about four feet thick, he shows are impervious to sound. The same gases diffused through each other are pervious to sound. Similar kind of phenomena occur in similar

circumstances with other vibratory motions, as light and radiant heat. Hence, two gases diffused through each other possess a quality which is not the average of the same gases alternated in small bulks, but which appears to be of a distinct kind. No evident solution of this problem occurs on the atomic theory. If ether permeate all bodies, and be the medium of transmission, it is both a conductor and non-conductor of electricity, both opaque and transparent to light, both diathermous, and a heat-absorbent; but as this is an evident absurdity, the utmost transparency of solids and fluids to light, radiant heat, electricity, sound, &c., is due to unbroken atomic continuity in at least one direction. But the metal potassium before alluded to is a conductor of electricity, and, therefore, its substance is continuous. Faraday, however, showed that 680 parts of it together with 2744 units of other substances could be compressed into less space than was originally filled with 430 parts of potassium itself; and it is difficult to avoid the conclusion that potassium is elastic; and, if potassium, then all other bodies—solid, fluid, and gaseous.

It is difficult to trace mentally the act of elastic disturbance within the substance of a body, but this difficulty is equally great with ether, and not more difficult with tangible than with intangible matter, and it is more in accordance with scientific method to connect a known or evident property with a known substance which exhibits similar qualities, than with an unknown substance whose mere existence is hypothetical.

Attraction of cohesion, one of the most evident properties of atomic matter, is intimately related to elasticity; but the atomic theory does not explain how. As the present object is rather to criticise an existing theory than to construct a new one, it is unnecessary to account for what the atomic theory leaves obscure; but it is somewhat probable that the true explanation lies in a direction we proceed very incompletely to indicate: mechanically, motions that coincide coalesce without jarring or "interference;" motions that do not coincide jar and tend to separate.

Another experiment of Tyndall's exemplifies these remarks. Holding a glass tube of about six feet long, and two inches diameter by its middle, he rubbed one end of it with a wet cloth and caused it to emit the sound of a musical note from the longitudinal vibrations thus excited. The free end of the tube was shaken into pieces; each piece a ring, and many of them with cracks quite round the tube, but not completely through its substance. It would require a

weight of about 100 tons to produce the same effect by dragging the glass tube asunder against its attraction of cohesion.

The vibrations, due entirely to the elasticity of the glass, passed to and fro the length of the tube, and were reflected from the ends and from any intermediate "nodes." A series of reflected vibrations thus met a direct and distinct, and not coincident, series of vibrations; and this jarring or interference of vibrations, themselves dependent upon the elasticity of the glass, sufficed to overcome, simultaneously, the attraction of cohesion of its substance at many different points of its length, thus showing that cohesion and elasticity are intimately related, and that the form of the motion governs much of its effects. This latter fact is also exemplified in many other ways. Amongst these are Abel's experiments on exploding gun-cotton by detonating powder. A small portion of common fulminating powder produces a most powerful explosion of the cotton, under conditions where a much larger quantity of the more violent explosive, chloride of nitrogen, simply disperses the cotton, and will drive some of its unaltered fibres into oak, &c., without producing any remarkable explosion of any part of it.

Amongst other instances are Professor Reynolds's bursting of the glass tube by an electric spark, and the difference of fracture in a pane of glass by a slow moving stone and by a rifle bullet.

The effect of a rapid blow on water in an open vessel is another illustration. A "Prince Rupert's drop," broken under the surface of water in an open phial, will break a phial that is unharmed if water is absent.

A fact connected with the spheroidal state of liquids is also significant. A quantity of water on a red-hot solid in the well-known spheroidal state is exploded if struck a smart blow, or if the water be dropped upon the heated surface from a sufficient height an explosion ensues. Recently, at an alkali works in Newcastle, serious damage followed from this cause—the instrument being a falling hot "black-ash ball." A still more serious case is on record of a copper foundry being destroyed from a workman spitting into a large quantity of melted copper.

One remarkable characteristic of molecules has been pointed out by Sir John Herschel, who says, in effect, that the exact equality of each molecule to all others of the same kind gives it the essential character of a manufactured article, and precludes the idea of its being eternal and self-existent, and this thought well deserves careful examination.

There appears no difficulty in appreciating the very precise equality of two distinct but otherwise identical musical notes. We can understand that two bodies may make the same number of vibrations in a second, and that two sounds may be identical, excepting in order of time. We can understand that the vibrations of light and heat of two distinct lines of rays may be of the same length, amplitude, and frequency, and so give the same appreciable results of light, colour, temperature, and mechanical force.

When, however, we examine natural objects, we never find two alike; there is always an observable difference. In this sense the multitude of individual facts is overwhelming; and two natural objects, whose only difference is that they occupy different portions of space, or occur at different times, are unknown. There are differences between two tuning forks, each sounding the same note. We must conclude that, as each fork changes with use and time, so it has changed between two soundings, although its sounds may remain unaltered.

Different but otherwise identical vibrations of sound and light have been compared, and have always been found to be the same; whilst all attempts to prove or to obtain perfect resemblance between any two solid, or, so to say, natural, objects, have been failures. Hence, identity of all active properties is more probably due to identity of motions than to identity of quantities or forms of the substances.

Adding to these conclusions the almost axiomatic idea that all force is motion, the enquiry, as to the necessity for an elastic ether, is restricted to the capacity of tangible or atomic matter for conveying vibrations of all kinds.

It is unnecessary for this purpose to discuss the question as to the definite size of a molecule, defining that term as the smallest portion of a substance that will produce the phenomena, whereby the individuality of the substance is recognised. There is no *à priori* reason why that molecule should not be of a definite size in comparison with the definite number and kind of vibrations it has to originate or transmit, and by which alone its characteristics are recognised.

Sound is not produced by one movement, but by a series of movements, and one movement alone is inaudible. Similarly it is probably true that all observable phenomena of this kind are due to a not indefinite succession of vibrations. Mentally, we can isolate each vibration, but practically no single vibration can produce a manifest phenomenon, such as we call sound, light, heat, or the like; and as one of the results of all chemical action is measured

by weight, the force called gravity must bear its part, and, hence, molecules may also be of a definite weight. To this extent there appear to be no analogical or inferential grounds for objecting to this definition of molecules.

The theoretic formulæ for the velocity of the propagation of sound show the velocities to be the same for each gas whatever be the pressure supported by it; and Regnault, by experiments on the large scale with pressures varying in the proportion of 1 to 5, has verified this law. This law is of general application to all vibrations in elastic media; hence, if light be propagated with an ascertained velocity in air, at the earth's surface, it should pass with the same velocity when air is indefinitely attenuated. Astronomers do find that light passes through our atmosphere, and through stellar space with the same velocity; and so far, therefore, as the sun beam is concerned, this space may be filled with attenuated air, instead of the hypothetic ether, if the air be elastic.

The preceding remarks have incidentally illustrated the axiom that all force is motion, and different forces (gravity included) are different modes of motion; but passive existence, and consequently passive qualities, ready to yield more or less to motion of some kind, appear also to be necessary and axiomatic attributes of matter. We cannot make lace without mechanism. The machine possesses various passive qualities; amongst them is the capacity under certain conditions of making lace by the expenditure of energy in the form of mechanical, as distinguished from molecular, motion. Various machines differ in their capacity of transforming an identical energy, and producing from it various results. Whilst different chemical compounds may be compared to different machines, all constructed out of a few materials, and still fewer mechanical elements variously grouped, all the different natural forces, *i.e.* vibrations of all kinds and forms, must be conveyed by one and the same quality, and that most probably a passive quality, common to all matter.

Continuous atomic matter appears to possess this quality to perfection. The waves of the sea are in number complicated beyond computation, and cross each in all possible directions. They descend below the surface, and in a definite zone we perceive the substance of the sea must be in intestinal motion correlated to the visible motion of its surface. The waves of a lake of gas (and those of a large mass of carbonic acid gas, just rendered visible by suspended carbonate of ammonia, are mentally reproduced as these lines are written) are at least as

interesting, philosophically, as the waves of the sea, and enable us more easily to understand how multitudinous vibrations may coexist in an elastic body which as a whole is stationary.

Sir Charles Wheatstone's experiment helps to carry this same idea much further. The tones of a tune played on a piano are conveyed through a wooden rod, and rendered audible in a distant room. Various fundamental notes of different intensities and in different sequence as to time, accompanied by their overtones or clang, and all the mechanical noises due to the mechanism of the piano, &c., pass through a wooden rod, thinned at its end to stand without interruption between two strings, and so rest on the sounding board.

The wooden rod may be replaced by a glass rod, or by a metal rod, or by a column of fluid. That air conveys these sounds is our daily experience.

At the same time that sonorous vibrations pass, we may pass heat, light, electricity, or magnetism, and if a suitable fluid medium be employed, mechanical waves and motion and chemical action may also simultaneously proceed.

Through the Atlantic cable two messages can pass at the same time from different directions. We talk across each other, and at the same instant hear many sounds from different directions; and an indefinite number of people can together see numberless rays of light reflected from the same point on a reflecting surface, and countless rainbows refracted in one rain drop.

From a seed may grow a tree, and from the tree a forest. The germinating cell or group of cells in the seed possess motion of such a form that its communication is the cause of this development; and the development from this cause occurs in, and is communicated by, continuous atomic matter. In continuance and complicity, the communication of motion constituting vegetable and animal vitalism or growth has no known parallel. Tangible matter, therefore, does transmit forms of motion of all kinds, and appears to be elastic; and if elastic, needs no medium for transmitting motion, and the so-called necessity for the hypothesis of ether disappears.

The conclusion, then, must be, it is more philosophical to endow appreciable matter, even hypothetically, with the qualities it appears to possess, than to create matter of an unknown kind in order to endow it with qualities we see, but refuse to appreciate, in matter that lies before us.

XUM

V. EXHIBITION OF APPLIANCES FOR THE PRODUCTION AND ECONOMICAL USE OF FUEL,

IN CONNECTION WITH THE

SOCIETY FOR THE PROMOTION OF SCIENTIFIC INDUSTRY, MANCHESTER.

THE chief object of the promoters of this Exhibition has been to concentrate the attention both of producers and consumers of fuel upon the great question of economy, and through the medium of the Society to bring together those who are concerned in the speedy solution of the problem.

The following was the original classification to which the council asked the attention of the exhibitors. No exhibitors have been named in classes 6 and 7; and 3 and 4 it has been found convenient to amalgamate.

(1). Appliances which may be adapted to existing steam furnaces, &c., whereby an improved combustion of the fuel is secured, and a direct diminution in the quantity required is effected.

(2). Appliances which may be adapted to existing steam boilers, &c., whereby the waste heat of the flue gases or of exhaust steam is utilised.

(3). Appliances which may be adapted to existing steam boilers, pipes, and engines, whereby loss of heat from radiation and conduction is prevented.

(4). Appliances which may be adapted to existing steam boilers and engines, enabling them with safety to realise the great economy resulting from the use of high pressure steam or superheated steam.

(5). New or improved furnaces (using solid, liquid, or gaseous fuel), boilers and engines of all descriptions, specially adapted for the saving of fuel.

(6). Apparatus which, by producing a cheap and abundant gaseous fuel, will supersede the costly carriage of coal, obviate the present enormous waste attending its use in the solid form, and condense and save the valuable sulphur, ammonia, and other by-products of the distillation now injuriously affecting iron and other smelting processes, and in a vast number of operations discharged as poisons into the air.

(7). Apparatus or engines for obtaining power advantageously from heat through any other medium than steam.

(8). Natural and artificial fuels of all kinds.
(9). Coal-cutting machines. Peat-manufacturing machines.
(10). Domestic and other fires, stoves, ranges, and apparatus of all kinds (using coal, gas, or other fuel) for cooking, and for warming rooms and buildings.
(11). Mechanical or other arrangements for securing the delivery of proved weights of fuel to the domestic consumer.

Entering at the south door is seen a wooden model of Davey's Patent Differential Expansive Pumping Engine, 200-horse power, for the New Hartley coal-pit; the engine is intended to lift 1500 gallons of water per minute 420 feet high. This is exhibited by Hathorn, Davis, and Co., of Leeds.

On the right-hand side of the building the first object which engages our attention is Erskine's Patent Economiser. This consists of 10 horse-shoe pipes about 4 inches in diameter, and all connected; these are placed in the flue communicating with the chimney. The waste heat from the boiler fire encircles these pipes, and causes the water which flows through them to enter the boiler at a temperature of 280° F.; and as these pipes are liable to become covered with soot and dust, instead of having a scraper, as in many instances is done, a pipe about 2 inches in diameter passes through the entire length of the horse-shoes, which is perforated with holes about 6 inches apart. The pipes are allowed to get hot, and the steam is now blown on to them, which, according to the inventor's statement, effectually cleanses them. The advantages which Mr. Erskine claims are, that from the peculiar form of his economiser, it causes no diminution or obstruction to the draught in the flue. It maintains a thorough circulation of the water through all the tubes, thus preventing the accumulation of scale; it is easy of access to every part, so that if one of the pipes is injured it can easily be replaced.

Andrew Bell shows a fine set of spiral economisers; they have the exact shape of three condensing worms put together. Each worm consists of 70 feet of pipe, and a three-coil machine is sufficient for a 40-horse boiler. Mr. Bell has shown great ingenuity in the casting of these iron worms; it would not be an easy undertaking to cast the worms in one piece—in fact practically impossible. The spirals are cast in half circles, having a spigot and facit joint. The joints fit so well into each other, that the circle can be formed and lifted without the joints parting; moulding boxes are put round these joints, and hot metal run upon them, so that it forms a perfect spiral when they are all

connected. This arrangement does away with all flange joints, so that no leaking can possibly occur, and also secures a perfectly smooth surface for the action of the scraper, which revolves, ascending and descending according to the spiral form of the coil. It is said that a saving of at least one day's consumption of fuel per week is effected. The water having a continuous circulation, all sediment is held in solution and passes through the coils, thereby avoiding deposit. Each coil is tested to a pressure of 300 lbs. per square inch before leaving the works. Economisers of various forms make a great show, and it is difficult to say which is the best.

Messrs. Twibill, of Manchester, exhibit a fine perpendicular economiser, which consists of a collection of tubes set vertically in the flue. These tubes are tested to a pressure of 500 lbs. to the square inch. Some experiments were performed some time since after the heater had been in use for some time. The first test was taken at six o'clock on Monday morning; the temperature of the water in the pipes was 140° F. At four o'clock on the same day it had risen to 284° F., on Friday morning at six o'clock the temperature was 250° F., and at four o'clock the same day it had risen to 310° F.; and the average temperature of the water throughout the week was 273° F. An experiment was performed at Messrs. Romaine and Callender's mill, and the average temperature of the water was 295° F. The scrapers are peculiar to Twibill's machine; they meet round the tubes and have chisel edges, which, by a special arrangement, press against the tube, and actually cut off the soot and tarry matter which accumulates upon the pipes.

Messrs. Green, of Wakefield, exhibit the finest vertical economiser; the joints of their economiser are all turned and bored socket-joints, "metal and metal" forced together by powerful machinery expressly adapted for the purpose. Their economisers are in operation to 65,000 boilers, representing 2,500,000 horse-power.

Nield's improved fuel economiser is on the same principle as Andrew Bell's. This economiser is arranged in sections, each section consisting of a number of cast-iron ring-shaped pipes, through which the water is caused to circulate. The inlet and outlet passages of each ring are close together; and as this is the sole joint, and the only fixed point in the ring, it is quite impossible that the expansion and contraction of the ring can affect the joint in any way; this is a very important advantage, and is peculiar to this economiser.

Robert and Joseph Ellis, of Liverpool, show some ingenious fire-bars, in which the water, before it enters the boiler, is made to traverse these bars, and is raised to a temperature of 300° F. There are many other appliances for heating the water before entering the boiler; there is the Paxman Water-Heater, in which waste steam from the engine is condensed, and so made to heat another supply of water, and the water is pumped into the boiler at a temperature of 200°.

Goodbrand and Holland show a coal-cutting machine. It is a 27-inch self-acting right or left hand coal cutter, constructed specially for the Wharncliffe Silkstone Coal Company to undercut their medium hard coal at bottom of seam.

Messrs. Ommanney and Tatham also have Winstanley's coal-cutting machine. This machine is designed for holing in mines which are worked on the wide work or long wall system. It is driven by compressed air, the pressure required being from 20 to 30 lbs. per square inch, according to the nature of the coal to be cut. The height of the machine is 22 inches, and the gauge of the wheels can be made to suit any ordinary colliery tramway. The cutter holes its own way into the coal, cutting from nothing up to 3 feet or more in depth, the thickness of the groove being 3 inches. The small coal made by holing represents only from 25 to 35 per cent of the quantity of small coal produced by hand holing. The average rate of holing in hard coal, with a pressure of 30 lbs. per square inch, is 25 yards per hour, including stoppages, and this may be considered to equal the work which would be done by at least thirty men in the same time.

Messrs. Hanworth and Horsfall exhibit a self-feeding smoke-burner and fuel-economising furnace. The drawback to it is the complicated arrangement for effecting the object. The bars are moved by egg-shaped wheels, which gives them a forward and backward motion, and the coal is allowed to fall upon them by means of a sloping plane.

Some experiments were performed at Lacy Brothers, Callis Mill, near Hebden Bridge, upon two of Galloway's New Patent Boilers, 28 feet long, 7½ feet diameter, and working at 90 lbs. pressure, one of them fired by hand, the other by the self-feeding furnace. The results of tests show a gain of 15 per cent in favour of the self-feeder.

Results of Tests, January 22, 23, 1874, at Messrs. Lacy's.

Firing.	Time. in hours.	Coals Used.		Water Evaporated.	Pounds of Water Evaporated per lb. of Coal.
		Cwts.	Lbs.	Gallons.	
Hand-fired . .	10·5	75	0	7150	8·42
Self-feeding . .	10·5	69	26	7700	9·93

William Young, Brothers, Queen Street, London, show a Smoke Preventer with spiral bars, for every description of furnaces, grates, and stoves. By means of this apparatus the fuel is introduced at the bottom of the fire, under the burning coals, and thus the production of smoke is prevented. The smoke preventer is composed of spiral bars mounted on an axis, which is moved by hand or machinery each time coals are required; in an ordinary fire-grate, there is a small trough at the bottom, in which works an axis carrying two vanes of fire-bars. The coal is put into the trough, and the poker is used, not to poke the fire, but to turn the fire-bars round, thus turning the fresh coal under the ignited coals.

Messrs. Piercy, of Birmingham, exhibit an apparatus called a Mechanical Stoker, patented by Dillwyn Smith. It is a very ingenious arrangement for feeding the furnace mechanically. In front of the fireplace is a cylinder about 4 feet long and 8 in diameter; up the top of this is a hopper which will hold about 5 cwts. of coal. In the cylinder revolves two Archimedean screws, one right and one left, which carries the coal into chambers, one underneath each screw. In these chambers revolve two fans, which throw the coal the whole length of the furnace, the quantity of coal being regulated by the requirements of the boiler.

Mr. Sudlow, of Oldham, exhibits a Rotary Engine, the advantages of which are as follows:—It obviates the dead points or centres of the crank, and consequent ever-varying leverage, the steam acting at an uniform distance from the centre throughout its entire travel. It also gives an increased longitudinal capacity, wherein to expand high pressure steam without incurring pressure, as in the case of compound engines; also, where necessary, the flywheel can be entirely dispensed with.

Reese and Gledhill show Wright's Patent Movable Fire-Bar. The rapid and complete manner in which they operate upon the combustible matters used decreases the formation of clinker or slag, by removing the refuse while in a state of dust before it has time to cake into a clinker. By their peculiar advancing and retiring action, the slag that is formed at the extreme back of the surface is brought, with every

successive action of the bars, and deposited on the dead-plate or mouth of the furnace. This is an advantage of the greatest importance, as the removal of slag from the extreme back of furnaces has always been attended with great difficulty and the periodical destruction of the fire. A thorough and complete combustion is effected by the breaking up and removal of the slag, and consequent free admission of air between the bars, and a large saving is effected in the usual consumption of coal.

Mr. Gall, of Halifax, shows a Patent Self-Acting Smoke Preventer, with the recommendation that it will reduce the smoke emitted from the chimney by seven-eighths; and should this result not be attained the purchaser may, within one month, return the Preventer to the patentee, and no charge whatever will be made.

Dingley and Son, of Leicester, exhibit Lake's Coal Economiser, which, according to the statement of the patentee, will save from 10 to 15 per cent on stationary boilers, and from 20 to 25 per cent on multitubular boilers. This arrangement consists of a conical, fluted, or corrugated valve, applied to the rear end of the tube, and capable of being adjusted as required; the openings round the valve being the outlet for the draught, and which are proportioned to the area over the bridge, cause the fire to be kept in close contact with the plates around and throughout the entire length of the tube, ensuring more perfect combustion and equal distribution of the heat within the boiler. It is applied without in any way altering the boiler or interfering with present draught.

The Messrs. Howard, of Bedford, show their celebrated Safety Boiler; and among the leading features of this boiler are, safety (every boiler is tested to three times its working pressure, and the bursting pressure of the tubes is at least 1500 lbs. per square inch), great simplicity of parts, facility of repairs, and durability. In the Howard Safety Boiler there are neither seams nor rivets, and no joint is exposed to the direct action of the fire; the tubes are counterparts of each other, and every part is made on the interchangeable principle; and it is more readily accessible, both internally and externally, for thorough inspection and cleaning than almost any other form of boiler—high pressure steam with economy of fuel. With this boiler a pressure of 120 to 140 lbs. per square inch is more secure than ordinary boilers working at 50 lbs., while experience has shown that on the great question of the economy of fuel the hopes entertained that the higher pressure of steam would, under proper

conditions, lead to an important saving of coal have been realised.

A similar boiler is shown, and called the Safe and Sure Boiler, by the Patent Steam Boiler Company, of Birmingham. They claim for their boilers absolute safety from explosion; this advantage is obtained by the subdivision of steam and water in small tubes tested to a pressure of 500 lbs. to the square inch. If a tube should burst, the only result would be a rush of steam and water into the furnace, a sudden lowering of the steam pressure, and the extinction of the fire. A boiler is often thrown aside as useless nine-tenths of which is practically good, but from the remaining tenth having failed the whole has to be rejected; with this boiler that one-tenth could have been replaced by a new one in perhaps less than two hours, when the whole would have been as good as ever. The nature and disposition of the heating surface in this boiler are such as cannot fail to fully utilise the heat applied, while the internal arrangements are such as entirely prevent the escaping gases becoming much above the temperature of the steam, and ensures, with an ordinary amount of attention, perfect consumption of the smoke.

Mr. Stanley, of Sheffield, shows his Patent Furnace for Smelting Ore. The advantages of these furnaces are, in the first place, they effect a saving of from 25 to 30 per cent in fuel. The use and expense of grate-bars are dispensed with, as these furnaces have closed fire-places formed in brickwork; they make from 80 to 90 per cent less ash than open fire-grate furnaces, the workmen have much less labour in working these furnaces, and the heat is quicker and more under the control of the furnace men.

Bailey and Co., of the Albion Works, Salford, make a very fine show of Pyrometers, Hallam's Ejectors, Oil Testers, and other useful inventions. Bailey's Patent Pyrometer is used for indicating heat, saving coal, and promoting uniformity of production in malt-kilns, ovens, and in other places where a certain degree of heat is requisite. The pyrometer for malt kilns is 4 feet long, and has an enamel dial 4 inches in diameter; the dial is indicated at 300°—black figures on a white ground. One of these pyrometers has been tried at the Valley Mill, near Holyhead, and the proprietor has tested it and found it very sensitive at any change of temperature, enabling the man to keep his kiln at the proper heat, which is very important in malt-kilns. These pyrometers are also used by the Government departments for baking bread; it is also used for indicating the waste heat in flues of works and locomotives, for indicating the

temperature of blast-furnaces, gas retorts, and other useful purposes where high temperatures are used.

Bailey's Oil Tester is a very ingenious instrument for finding out the value of oils as lubricants; and if good oil is used for lubricating, it reduces friction in the machinery, and thus saves coal and wear and tear. The tester may be briefly described as a piece of 3-inch shaft and two brass steps, upon which frictional pressure is obtained by weighted levers; a thermometer is fixed upon the machine, to denote the temperature. One drop of oil is put on to a drum of 3 inches diameter, friction is applied, and the "life-time" of the oil (which is the technical term) is indicated by means of a speed indicator, which indicates the number of revolutions required to raise the temperature a given number of degrees. The exact money value of oil may be arrived at as follows:—Suppose a certain quantity of No. 1 oil on the machine shows 200° by being driven 10,000 revolutions, No. 2 oil shows 200° and 7500 revolutions, or 25 per cent less value. In addition to this practical way of obtaining a result, the machine may be driven to a higher temperature, to see which oil produces the worst residue. In testing various oils, a certain weight or measure must be taken; the thermometer should always indicate the same temperature at starting. It is found that 200° F. is the best to try all oils to, if their lubricating power is to be consumed, and the machine should be always driven until that temperature is indicated, and then immediately stopped; the bearings of the spindle should be well oiled, to prevent friction in the wrong place; when a temperature of 200° has been obtained (the speed index showing zero at the start), it should then be seen the number of revolutions taken to produce the temperature. After testing the oil, it is directed that the machine be stopped, and the oil is to remain on the machine, and in twelve hours after it is to be tested again to see how soon 200° can be obtained; the second experiment will indicate which oil is the inferior on machinery when stopped. The following is a short table of results on trying these various kinds of oil:—

Quality of Oil.	Temperature produced.	Total indicated Speed of Three Tests.	Market Price per gallon.	Real value of the Oils, taking No. 1 as a standard.
			s. d.	*s. d.*
No. 1.	200	120,000	6 0	6 0
No. 2.	200	180,000	4 0	9 0
No. 3.	200	60,000	2 6	3 0

It will be seen that No. 2 oil will allow 50 per cent more

revolutions to be performed than No. 1, and must therefore be worth 50 per cent more money.

Messrs. Johnson and Hobbs, of Manchester, exhibit a model of a Patent Apparatus for the Condensation of Smoke, Gases, &c. This apparatus is exceedingly simple and inexpensive in its construction; it is on the paddle-wheel principle, with an addition of projections on the blades to produce a finely-divided spray of water, which falls through a series of network composed of laths, brushwood, shingle, or other material, and is so arranged as may seem best for arresting the substances to be operated upon. The same liquid may be used over and over again, until charged to any extent that may be desired. The inventors declare that this machine will be found more effective than the expensive condensing towers now used for the purpose, as it produces a powerful draught, which can be regulated at will, and the solution can be made in the machine as concentrated as may be required. The machine has been tried in condensing ammonia, and has been found to succeed thoroughly; the working parts of the apparatus can be arranged to resist the action of hydrochloric and other powerful gases affecting metal work.

Crossley Brothers, of Manchester, exhibit an Atmospheric Gas Engine. This engine works as follows:—Gas and air, mixed in such proportions as to give a mild explosive compound, are admitted under a piston which slides air-tight in a vertical cylinder open at the top. The compound is ignited, explodes, and the explosion drives the piston upwards. The ignited gases, having increased in volume, lose their heat; their pressure becomes less as the piston rises, and when it has got to the top of the cylinder a partial vacuum is formed, and the pressure of the atmosphere makes the piston descend. The work thus done steadily by the atmosphere during the return stroke of the piston yields the driving power, which is transferred to the shaft by suitable mechanism. This utilisation of the instantaneous power of the explosion, by allowing the piston to fly up freely from it without doing other work than emptying the cylinder of air, is the basis of the economy and success of these engines. The sudden energy of an explosion cannot be economically applied to push a piston slowly along against a load, as in the case of steam-engines; it is thus that other gas engines have been superseded by this patent. Some of the advantages of this engine, compared with steam engines, are that it can be started at a moment's notice, and will at once give out its full power; thus no

time is lost in waiting to get up steam. The attendance required is exceedingly small, averaging one hour per day for a man, including cleaning, oiling, stopping, and starting. The fuel has not to be got into the house, nor ashes to be got out; gas is laid on, thus much trouble is saved. No constant supply of water is required; a quart a day suffices. Gas at 4s. per thousand feet will feed the engine at one penny an hour per horse-power. Gas can only be burnt in exact proportion to the power required; this is controlled by a governor. These engines cannot be used for high horse-power; from one to two horse-power is the most they can be used for. From the many testimonials received, it seems that the cost of gas is less than one penny per hour.

The show of fire-grates, kitchen ranges, various kinds of coal savers, is very good, and perhaps the most complete in the Exhibition. The grates, &c., are all in use in the third annexé of the building, so that spectators can judge for themselves as to the relative merits of the various inventions. What would have made this show still more interesting would have been to have given the weight of coal consumed by each fire during the day to produce the desired effect; as it is, one sees an interesting collection of machines for saving fuel, but no experiments seem to have been performed by competent judges to test the truth of each inventor's statements. There are various grates for utilising the waste heat of the fire and causing it to warm air-chambers, which warm air is carried to different rooms in the house.

Shillito and Shorland exhibit patent grates and hot-air boxes for extracting waste heat from every description of grates and kitchen ranges, thereby effecting a saving of at least 50 per cent in fuel, without at all interfering with the general appearance of grates. One of their 30s. boxes can be inserted behind register or sham register stoves now in use, and could also be placed behind a kitchen fire without taking down the range or grate, and, according to the inventor's statement, will raise temperature in excess of external atmosphere from 10° to 20°, and discharge into room or lobby 2000 cubic feet of warm air per hour. The advantages of this fire-box grate over the ordinary grate are, that it secures a supply of perfectly fresh, warm, pure air, and diffuses it equally over the whole room, or rooms requiring to be heated, the cold air admitted from the outside being perfectly fresh, and warmed by passing over the inside back of the grate. The objection to other hot-air stoves, that they draw their supply from the already vitiated

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air of the room, is obviated. When this grate is used in dwelling-houses two rooms can be heated by the same fire—the open fire serving for one room, and the heated fresh air being thrown into the next.

Thomas Whitwell exhibits a grate on a similar principle. By his fire-place he injects warm air into the room at a temperature between 65° and 115° F.

Rogerson and Co. show Corbitt's Improved Economic Warming and Ventilating Grate. It is simple in construction. The best points of the modern grate are preserved, viz.—The cheerful open fire; large reflecting and radiating surface; reduced size of fire-box, with convex back, which is composed of fire-brick, and, being a bad conductor, throws the heat into the room; the draught-flue, opening into the chimney, is regulated by Louvre valves, so that no waste heat need pass up the chimney beyond the products of combustion.

The most successful and ingenious fire-grate in the Exhibition is the invention of the Rev. J. Wolstencroft, and is called the Vacuum Draught. The inventor says the great difficulty is solved, viz., "how to get a healthy, cheerful fire, imparting a genial heat, with half the amount of fuel commonly used." We saw the grate in use, and we must candidly admit it was the most cheerful and the brightest fire in the place, but as to the amount of coal it daily consumed we are unable to say. According to some experiments which have been performed with it by James D. Curtis, Commander Royal Navy, there is truth in the inventor's statement, that there is a great economy in the consumption of fuel. Captain Curtis, of Brimpsfield, Gloucester, experimented with the grate in his harness-room from the 18th of August, 1873, to the 1st of September, 1873, using no other fire, burning slack coal delivered for 24s. per ton, employing this fire daily for cooking small things, such as boiling potatoes for the fowls, &c., and after the daily use the fire was left to burn itself out during the night; the cost of coal pe day was 3½d. The front of the grate is continued down to the floor, cutting off the supply of air from within the room; by this means an air chamber is formed under the grate, to which the air is communicated from within or without the building, bringing the draught under and directly through the fire-bars. In a fire-grate which has been fitted up in Manchester, at the office of one of the Local Boards, the air-chamber communicates with the main sewer, and draws its supply from thence, thus, as it is supposed, ventilating the sewer,

at the same time consuming the noxious sewer gases. Any kind of fuel can be used, and very small coal can be burnt as easily and with as good results as lumps; coke and cinders may be burnt over and over again, until they become as fine as sand. The ashes from the fire all drop through the bottom of the grate into or through the air chamber, consequently dust from the fire is greatly diminished in the room; the draught may be regulated at pleasure with a valve. The invention may be easily applied to many existing grates at the cost of a few shillings.

By the side of Wolstencroft's fire-place was Kenyon's Patent Coal Saver, which consists of a perforated fire-brick tile, to put into the grate and fill up the coal space, throwing the hot coals to the front of the fire-place, while the back of the fire is comparatively cold. It has the disadvantage of presenting a very dull fire while it is carrying out its principle of saving coal, presenting a great contrast to Wolstencroft's; indeed one might almost think it was placed there as a foil for his more successful competitor.

Crawshaw's Household Coal Saver is a corrugated piece of iron or clay placed behind an ordinary coal-fire. It radiates the heat from the fire into the room, instead of allowing so much waste heat to pass up the chimney.

Frisbie's Patent Feeder and Grate is a most ingenious arrangement for feeding a fire with coal from the bottom. This feeder and grate provides a simple method of feeding fuel up, from underneath the fire, into all descriptions of furnaces, fuel-boxes, and fire-grates. By this principle of feeding from below the fire there is no fresh consumption of the fuel, the igniting of the fresh coal is a gradual process, while at the same time a very intense heat is obtained. The hottest portion of the fire being constantly at the top utilises the heat, and preserves the fire-bars from being burnt out; the heat of the surface of the fire is not abated by the supply of fresh fuel, and no cold air is admitted to the furnace while feeding, thereby preserving a perfectly uniform heat. By feeding from beneath, the coal is pushed up and outwards equally from the centre of the grate, and is evenly consumed, with scarcely any refuse except fine ashes, which drop down through the grate-bars without raking. From various testimonials which the inventor has received, it seems that there is a great saving in the use of the coal; thus one firm says their coal bill averaged £160 a month, but on introducing one of these burners they only used that quantity in four months.

Folloms and Bate, of Manchester, exhibit a large collection of stoves and fire-grates. One of their novelties is a Portable Water-Boiler, which consists of an upper and lower chamber, and is so constructed that the upper chamber is filled with cold water, and as the hot water is drawn off from the lower, the cold water is allowed to fall down through a small pipe, so that there is a constant supply of warm water. It will boil 11 gallons in 20 minutes, or three or four hundred persons can be supplied with hot water for tea at a cost of 3 lbs. of coal.

There is a very good show of various kinds of peat and patent fuel, with the necessary apparatus for condensing and purifying peat.

Kidd's process for carbonising peat consists of a large chamber or drying-room connected with a boiler which supplies superheated steam; from the boiler a steam-pipe passes through the furnace, and from thence into the flue: the steam, in its passage over the boiler-fire, becomes superheated, and, together with the smoke, passes into the drying-chamber; the peat, cut into pieces about the size of bricks, is put into a framework which runs upon wheels, so that it easily runs into the drying chamber, and is run out again when finished, thus saving a great deal of labour. The object of Kidd's process is the collection of the heated gases referred to in a closed chamber, where they may be usefully employed in charring peat, or converting it into charcoal; an artificial draught is created by jets of superheated steam, and the whole products of combustion from the furnace are forced into and retained by the closed chamber. The chamber is filled with peat, which may be dried and charred in less than forty-eight hours by the action of the furnace-gases and superheated steam; the temperature of the chamber soon rises to between 300° and 400° F., and remains at some temperature between those limits. By charring the peat at a low temperature the loss of hydrocarbons is very small, the gases which are poured into the chamber being for the most part non-supporters of combustion; consequently it is impossible for the peat to take fire during the process of charring. The fuel used in the furnace which supplies the gases and generates the steam is peat which has been partially dried in the open air. It is estimated that a ton of peat charcoal can be produced by this method at a cost of 13s. 6d., which sum includes all charges for interest on capital, royalties, and labour; raw peat at 3s. a ton; that used for fuel, 4s. 6d. per ton. Peat thus prepared produces a gas of high illuminating power, ranging between

20 and 22 candles, and 6000 and 9000 feet per ton; the gas is generated so quickly that three charges of peat can be worked off to one of coal, thus effecting considerable economy in the plant of gas works. The charcoal which remains after the gas has been extracted is also much more valuable than the ordinary coal-gas coke. There is, no doubt, a large field open for commercial enterprise in the manufacture of peat charcoal, owing to its freedom from sulphur and its affinity for oxygen at a high temperature. It is equal to ordinary charcoal for refining iron, steel, and other metals. In France, this charcoal, under the name of *carbon roux*, is largely used in the manufacture of gunpowder; it has been used as a fertiliser also for filtering water and town sewage, and when combined with a proper admixture of phosphate of lime it has been found useful as a substitute for animal charcoal.

Henry Clayton and Son show some fine machinery for preparing and forming blocks of condensed peat. One of the difficulties in preparing peat for the market is to get rid of the large amount of water which it contains, as sometimes it is met with containing from 55 to 80 per cent. Of this, a variable proportion is "loose, or free water," much of which, when present in the larger quantity, can be extracted by means of drainage and squeezing; the great bulk, however, of the water is "locked up," confined in the rooty or fibrous portion of the peat. So retentive is peat of this fixed water, that no pressure, however powerful, can effect its expulsion while the peat remains in its natural condition. The objects which the Messrs. Clayton aim at are;—To get rid of as much water as possible by draining and squeezing, then to thoroughly cut up the fibrous or rooty portion, releasing the great quantity of water and air which was previously fast in the fibre, and reducing the whole to an uniform state of pulp. Peat thus prepared will freely and rapidly part with its moisture by natural evaporation, and in so doing will consolidate itself, and thus acquire a density which no pressure of the peat in its natural state could produce, becoming very hard and compact, and of a specific gravity nearly equal to coal; in this state it is (unlike the common prepared turfs) non-absorbent of water. The patentees of the condensed peat say that it produces little or no smoke, contains no sulphur, ignites more readily, and diffuses the heat more generally and more widely than coal itself, leaves no cinder and but little ash. To accomplish these objects with peat direct from the bog, the peat is filled (as dug) into squeezing-trucks, and during its convey-

ance from the bog to the machine much of the "free water" is pressed from the raw peat by a simple and easy means. From the trucks the peat is discharged into the machine, which, in its action, continuously cuts up minutely the fibrous portions of the peat, and produces a perfect admixture of the cut up fibre and rooty matter with the pulpous portion, thereby utilising the whole mass of the bog and entirely destroying its original character and natural spongy nature. In its travel through the machine the material further undergoes a moderate amount of pressure, and acquires a density and form permitting it to be discharged and deposited upon portable trays in blocks or briquettes of convenient size, and thence conveyed by a simple and labour-saving contrivance to the drying-sheds, where, after three weeks' drying (during average weather), the prepared peat becomes hard, compact, marketable fuel. A trial of condensed peat was made some time since for railway engines on the Belfast and Northern Counties Railway, with a view of testing its qualities as a fuel for locomotives. The engineers who made the trial say: "In order carefully to watch the power of the fuel in the generation of steam, we rode on the engine from Carrick Junction to Ballymena, a distance of twenty-seven miles. The pressure at starting was 100 lbs. on the square inch; the commencement of the journey was up an incline of about 1 in 80, 4 miles long, and with double curves. While going up the incline the pressure rose to 110 lbs., and afterwards to 120; the speed, whenever this was permitted, was 40 miles per hour."

Particulars of the above Locomotive Trial of Condensed Peat Fuel.

Total quantity of fuel used	14 cwts. 1 qr. 14 lbs.
Weight of train, including engine and tender	70 tons.
Number of carriages	Seven.
Miles run	74.
Time running	3 hrs. 9 mins.
Weight per mile used of peat fuel .	21·47 lbs.
Average pounds per mile for the last three months, using Welsh and Scotch coals at a ratio of 2 of Welsh to 1 of Scotch	25·25 lbs.
Average for the month of May last .	26·29 lbs.

The engineers conclude their report by saying:—"Having carefully noted all these facts, we have no hesitation in saying that we consider the condensed peat in every way well adapted as fuel for locomotive purposes."

A series of experiments have been made at the Commercial Gas Works, London, on condensed peat, the results of which are given below :—

Yield of One Ton of Coal.

Description of Coal.	Cubic feet of Gas.	Illuminating Power in Sperm Candles.	Cwts. of Coke.	Gas per ton. equal to lbs. of Sperm.	Sperm corresponding to Gas of Boghead Cannel No. 2, equals 100.
Staffordshire	7,100	12·42	13·5	302	13·6
Derbyshire	7,600	11·71	17	305	13·7
Lochgelly	8,000	18·00	13	494	22·2
Derbyshire Cannel . .	8,500	20·60	15	600	27·0
Wigan Cannel . . .	10,000	20·00	13·25	686	30·9
Newcastle Cannel . .	9,800	25·00	13·25	840	37·8
Lesmahago Cannel .	10,500	40·00	10	1440	64·8
Boghead (No. 1) . .	12,500	40·00	8	1713	77·1
„ (No. 2) . .	13,000	48·00	6	2222	100·0
Yield of One Ton of Condensed Peat.					
Belfast	10,500	15·65	8	562	25·3
Creavelea	9,240	18·75	8·75	594	26·7
Welsh	11,000	22·50	7	849	38·2

The following, from a tabulated statement giving details of the various peat enterprises actually now working, will afford some interesting information on peat manufacture :—

System.	Where Working.	Horse-Power.	Tons of Dry Fuel per Machine per Season.	Cost per Ton.	Relative Value of to Coal.
Hodge's Canadian Peat Company.	Montreal, for Grand Trunk Railway.	16	4000	6s. 6d.	5-6ths, or 84 p. ct.
Boston Peat Company.	New England States.	12	4200	8s.	84 p. ct.
Roberts, Pekin.	New York.	13	3500	8s. to 9s.	84 p. ct.
Haspalmoor. Colbermoor.	Bavarian Government Works.	Not stated.	Not stated.	12s.	60 p. ct.
Box's.	On trial.	16	Not stated.	Stated 4s. 8d.	—
Clayton and Son.	Great Britain and Germany.	6	3500	3s. 6d. to 5s.	Variable according to quality of peat.

From the foregoing it will be seen that peat fuel possesses a calorific power of five-sixths of coal, and can be produced in Canada and the United States at from 6s. 6d. to 9s. per ton, where wages for labour are not lower than 7s. per day.

The Peat Coal and Charcoal Company make a show of peat in all its stages, from the time it is taken from the bog to the time it is compressed and carved, for they have some pieces which have been cut into flowers and fruit, till it looks like carved ebony. This Company has bought the patent rights of M. Challeton de Brughat ; his process consists in making peat coal having nearly the same density as pit coal, and also he claims to have invented a better

method of preparing peat charcoal. The cost of this peat coal at the manufactories may be taken at 8s. per ton for small quantities, and 6s. to 6s. 6d. for large quantities. 1¼ tons of peat coal made by this process is reckoned to be equal to 1 ton of best English coal; for stowage it will only take, on an average, 20 per cent more room than ordinary coal. This Company intend to establish their first manufactory on the borders of North Wales and Shropshire. The peat on this land is of the best quality, averaging in depth about 12 feet. A trial of this peat was made on the Thames, on board the paddle-steamer *Times*, in the presence of the Duke of Sutherland and a distinguished company. The steamer ran from Beckton gas works to Greenwich in twenty-five minutes with a strong head wind, slack water at top of tide; and the quantity of uncompressed peat fuel consumed in this twenty-five minutes' run was about 210 lbs., maintaining a steady steam pressure of 50 lbs., without smoke, and at all times a good clear fire. The experimenters state that for the generation of steam it requires but a very moderate current of air, is absolutely smokeless, and gets up steam equally quick as coal, and maintains it with a less expenditure of fuel, does not injure the fire-bars, and is in every respect much cleaner than coal or coke.

The South of Scotland Peat Fuel Company exhibit fine samples of peat, which have been analysed and reported upon by Mr. Heddle, Professor of Chemistry in the University of St. Andrews. The composition of the dried fuel, on analysis by combustion, is—

Gas	60·293
Carbon, free	31·064
Ash	8·643

In its ordinary condition, however, it contains—

Water	16·740
Gas	50·200
Carbon	25·864
Ash	7·196

It was found that a sample kept for some days under cover contained 16·4 per cent of moisture, and that samples artificially dried regained upon exposure nearly the above amount, so that it may be held to be impracticable to improve the fuel in this respect; the fuel yields gas at the rate of 7984 cubic feet per ton. When examined by Lewis Thompson's fuel test-apparatus, the calorific power of the fuel was found to be—

In its usual state . . .	4·675
When dried	5·940

That is, one part of the fuel will boil off as steam above $4\frac{1}{2}$ times its own weight of water from 212°, and the dry fuel about 6 times its own weight.

Mr. A. C. Pelly shows his patent peat fuel, which he condenses into solid balls, of the density of hard wood; the peat balls, when manufactured ready for use, cost only about 5s. 6d. to 6s. per ton.

Professor Reynolds reports upon the process, which consists in pulping the raw peat in a horizontal cylinder, within which a shaft carrying a number of arms is made to rotate rapidly, by steam or other power. The fibre is not only broken in this machine, but, owing to a screw-like action of the shaft, the peat pulp is forced through a circular opening, and then appears as a cylinder of pasty material, which is cut into short sections by very simple apparatus; the short cylinders of pulp so obtained fall immediately into a truncated cone, revolving rapidly. Here each piece is made to assume a rough spherical form; these pieces are then dried. The dry product of these simple operations appears in the form of irregular balls; hence the term ball-peat. The following is Professor Reynolds's analysis of two samples of ball-peat:—

Hydrostatic moisture . .	15·12	14·87
Carbon	46·95	47·22
Hydrogen	5·01	5·14
Oxygen	29·83	31·22
Nitrogen	0·38	0·74
Ash	2·71	0·81

Professor Reynolds says:—It is well known that the heating effect practically obtained from ordinary rough turf rarely exceeds 40 per cent of that afforded by Staffordshire coal; this ball-peat possesses a heating value equivalent to 55 per cent of that of the class of coal mentioned, or, in other words, to produce the heating effect obtainable from 1 ton of average Staffordshire coal it is necessary to burn about $2\frac{1}{2}$ tons of ordinary turf, while 1·8 tons of ball-peat would give the same amount of heat.

Reuben and Israel Levy exhibit "Leigh's" Patent Phœnix Fuel, which consists of refuse from coal fires mixed with tar or pitch, and made into balls. We cannot see the economy of the process, as it leaves 75 per cent of ash; they claim the novelty of using the ashes *ad infinitum*.

Radeke's patent artificial fuel consists of small coal, bound together in blocks by the aid of silica, both in solution and in a powdered state.

IV. AN INVESTIGATION OF THE NUMBER OF CONSTITUENTS, ELEMENTS, AND MINORS OF A DETERMINANT.

By Captain ALLAN CUNNINGHAM, R.E.,
Honorary Fellow of King's College, London.

THE following paper is an investigation of the number of constituents, elements, and minors, in four classes of determinants, viz., in ordinary, symmetric, skew symmetric, and skew determinants. In calculations and investigations relating to determinants it is often useful to know these numbers independently of the actual formation of the individual constituents, elements, and minors. The investigation of these numbers will be found an interesting exercise in the theory of combinations, and leads to some remarkable symbolical relations.

The references are to Salmon's "Modern Higher Algebra," 2nd edition. The type of a constituent of a determinant of n rows will be written a^{yz}, and the *corresponding* first minor as A_{yz}, (as in Salmon, Art. 2.) All the constituents and all the minors of determinants in the following problems are supposed *finite* and *unequal*, except when expressly stated to be otherwise. Without this limitation the investigations to be given are not necessarily applicable.

I. *Number of Constituents in a Determinant.*

1. The number of constituents in an *ordinary* determinant of n rows is *in general* (*i.e.* if the constituents be all unlike) n^2.

2. In a *symmetric* determinant of n rows, the (n^2-n) constituents not in the leading diagonal occur in pairs, and are equivalent to only $\frac{1}{2}(n^2-n)$ different constituents, making up with the n different constituents in the leading diagonal a total of $\frac{1}{2}(n^2-n)+n=\frac{1}{2}n(n+1)$ different constituents *in general*.

3. In a *skew* determinant* the n constituents of the leading diagonal are in general different, whilst the remaining (n^2-n) constituents occur in pairs equal in magnitude, but of opposite sign, so that there are *in general*—

n^2 different constituents, but only
$\frac{1}{2}(n^2-n)+n=\frac{1}{2}n(n+1)$ constituents of different *magnitude*.†

* SALMON, Art. 37.

† A distinctive name would be convenient for this variety: the author suggests "sub-determinant."

4. An important variety* of the above classes of determinants is that in which *the constituents of the leading diagonal are all zero*, in which case the above numbers are to be all reduced by n: thus the number of constituents will be :—

(1). In an ordinary determinant whose leading constituents vanish, (n^2-n).

(2). In a symmetric determinant whose leading constituents vanish, $\frac{1}{2}n(n-1)$.

(3). In a skew determinant whose leading constituents vanish (this is styled a skew symmetric determinant†), (n^2-n) different constituents, but only $\frac{1}{2}n(n-1)$ of different *magnitude*.

II. *Number of Elements in an Ordinary Determinant.*

Let E_n be the number of elements in an ordinary determinant of n rows.

Then a determinant of n rows may be expressed *in general* as a sum of n different terms, viz., $\Delta = \Sigma_{y=1}^{y=n} (a_{p,y} . A_{p,y})$, where $A_{p,y}$ is the first minor of Δ corresponding to $a_{p,y}$, and is therefore itself a determinant of $(n-1)$ rows, and contains (by above notation) E_{n-1} different elements. Moreover, these E_{n-1} elements of *each* term of type $(a_{p,y} . A_{p,y})$ in the whole sum, which together make up Δ, are *in general* different from all the elements in every other such term.

Hence, $E_n = n . E_{n-1}$.

Similarly, $E_{n-1} = (n-1) . E_{n-2}$, and so on.

Hence, $E_n = n . E_{n-1} = n(n-1) . E_{n-2} = \ldots .$

$$= \frac{\lfloor n}{\lfloor n-r} . E_{n-r}$$

$$= \lfloor n . E_1$$

$$= \lfloor n \quad \ldots \ldots \ldots \ldots \ldots \quad (2).$$

(1).

since it is obvious that $E_1\ n=1$, $E_1 = 1$.

III. *Number of Elements in an Ordinary Determinant whose Leading Constituents Vanish.*

$$\Delta, \frac{d\Delta}{da_{pp}}, \frac{d^2\Delta}{da_{pp} . da_{qq}}, \frac{d^3\Delta}{da_{pp} . da_{qq} . da_{rr}}, \text{ \&c. } \ldots .$$

represent an ordinary determinant, and its *successive* first, second, third, &c., leading minors, the *leading constituents* (which are of type a_{pp}) being *finite*.

$$[\Delta], \left[\frac{d\Delta}{da_{pp}}\right], \left[\frac{d^2\Delta}{da_{pp} . da_{qq}}\right], \left[\frac{d^3\Delta}{da_{pp} . da_{qq} . da_{rr}}\right], \text{ \&c. } \ldots .$$

* See note on preceding page.

† SALMON, Art. 40.

represent the corresponding values of the preceding quantities when the *leading constituents* are all *zero*.
Also let $[E_n]$ be the corresponding value of E_n,

And let ${}^nC_r$ be the number of combinations of n things taken r together, so that—

$$ {}^nC_r = \frac{\lfloor n}{\lfloor r . \lfloor n-r} = {}^nC_{n-r} . $$

It is shown (Salmon, Art. 40) that in general—

$$ \Delta = [\Delta] + \Sigma \left\{ a_{pp} . \left[\frac{d\Delta}{da_{pp}} \right] \right\} + \Sigma \left\{ a_{pp} a_{qq} . \left[\frac{d^2\Delta}{da_{pp} . da_{qq}} \right] \right\} $$
$$ + \Sigma \left\{ a_{pp} a_{qq} a_{rr} . \left[\frac{d^3\Delta}{da_{pp} da_{qq} da_{rr}} \right] \right\} $$
$$ + \ . \ . \ . + \ . \ . \ . + (a_{11} . a_{22} . a_{33} \ . \ . \ . \ a_{nn}) \ . \ . \ . \quad (3). $$

Hence, noting that the number of ways in which a continued product, as $(a_{11} . a_{22} a_{33} \ . \ . \ . \ . \ a_{rr})$ of r constituents can be formed from the n leading constituents (of type a_{pp}) is ${}^nC_r$, also that the number of elements in an rth minor of type—

$$ \left[\frac{d^r\Delta}{da_{11} . da_{22} . da_{33} \ . \ . \ . \ . \ da_{rr}} \right], $$

(being a determinant of $(n-r)$ rows whose leading constituents vanish), is by above notation $[E_{n-r}]$, also that by the notation the number of elements in Δ is E_n, and in $[\Delta]$ is $[E_n]$, it results that—

$$ E_n = [E_n] + {}^nC_1 . [E_{n-1}] + {}^nC_2 . [E_{n-2}] + \ . \ . + \ . + {}^nC_r . [E_{n-r}] + $$
$$ \ . \ . \ . \ . \ {}^nC_{n-2} [E_2] + {}^nC_{n-1} [E_1] + 1. $$
$$ = [E_n] + \frac{n}{1} . [E_{n-1}] + \frac{n(n-1)}{1 . 2} . [E_{n-2}] + \ . \ . + \frac{\lfloor n}{\lfloor r . \lfloor n-r} . [E_{n-r}] + $$
$$ \ . \ . \ . \ . + \frac{n(n-1)}{1 . 2} . [E_2] + \frac{n}{1} . [E_1] + 1. \ . \ . \quad (4). $$

Now the numerical coefficients are the same as in the expansion of the binomial $(x+1)^n$, and the suffixes of $[E]$ are the same as the indices of x in that expansion; hence modifying the notation with the interpretation—

$$ \left. \begin{aligned} [E]^p &= [E_p], \\ [E]^p . [E]^q &= [E]^{p+q} = [E_{p+q}] \end{aligned} \right\} \ . \ . \ . \ . \quad (5). $$

that is to say, making the suffixes of $[E]$ follow the index law, Equation (4) takes the following remarkably simple symbolic form:—

$$ E_n = ([E] + 1)^n \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (6). $$

Further, this Equation being *general* for all (positive integral) values of n—

$$\begin{aligned} E_p.E_q &= ([E]+1)^p.([E]+1)^q \\ &= ([E]+1)^{p+q} \\ &= E_{p+q} \quad \ldots\ldots\ldots\ldots\ldots (7). \end{aligned}$$

that is to say, the suffixes of E *also* follow the index law, so that the notation may be further modified with the interpretation—

$$(E)^p = E_p \quad \ldots\ldots\ldots\ldots\ldots (8).$$

Hence, from Eq. (6) and (8)—

$$(E)^n = E_n = ([E]+1)^n \quad \ldots\ldots\ldots (9).$$

and this Equation being general for all (positive integral) values of n—

$$E = [E]+1, \text{ and } [E] = E-1 \quad \ldots\ldots (10).$$

These are symbolic relations between [E] and E of remarkable simplicity, and lead to an explicit formula for calculating $[E_n]$. For—

$$[E_n] = [E]^n = (E-1)^n.$$

$$= E_n - \frac{n}{1}.E_{n-1} + \frac{n(n-1)}{1.2}.E_{n-2} - \ldots + (-1)^r.\frac{\lfloor n}{\lfloor r.\ \lfloor n-r}.E_{n-r} +$$

$$\ldots + (-1)^{n-2}.\frac{n(n-1)}{1.2}.E_2 + (-1)^{n-1}.\frac{n}{1}.E_1 + (-1)^n \ldots (11).$$

IV. *Number of Elements in a Determinant out of whose n Leading Constituents only m are Finite.*

Generalise the notation of Problem III. as follows:—

Let $[\Delta]$, $[\Delta']$, $[\Delta'']$, . . . $[\Delta^m]$ represent the values of Δ (an ordinary determinant with finite constituents), when out of its *leading* constituents (of type a_{pp}) there are respectively none, one, two, &c., ... *m finite*, and the remainder zero.

Let $[E_n]$, $[E'_n]$, $[E''_n]$, : . . $[E^m_n]$ represent the corresponding values of E_n: by this notation $[E^n_n] = E_n$.

Then, by the same reasoning as in Problem III., and noting (in addition) that all terms involving the continued product of *more* than m leading constituents vanish necessarily in the case of the determinant $[\Delta^m]$, it follows that—

$$[\Delta^m] = [\Delta] + \Sigma\left\{a_{pp}.\left[\frac{d\Delta}{da_{pp}}\right]\right\} + \Sigma\left\{a_{pp}\,a_{qq}.\left[\frac{d^2\Delta}{da_{pp}.da_{qq}}\right]\right\} + .$$

$$+ \Sigma\left\{(a_{11}a_{22}a_{33}\ldots a_{mm}).\left[\frac{d^m\Delta}{da_{11}.da_{22}.da_{33}\ldots da_{mm}}\right]\right\} . (12).$$

$$\therefore [E_n^m] = [E_n] + {}^mC_1.[E_{n-1}] + {}^mC_2.[E_{n-2}] + . + {}^mC_r.[E_{n-r}] + \ldots + {}^mC_{m-1}.[E_{n-m+1}] + [E_{n-m}].$$

$$= [E_n] + \frac{m}{1}.[E_{n-1}] + \frac{m(m-1)}{1.2}.[E_{n-2}] + \ldots + \frac{\lfloor m}{\lfloor r . \lfloor n-r}.[E_{n-r}] + \ldots + \frac{m}{1}.[E_{n-m+1}] + [E_{n-m}] \quad \ldots (13).$$

Next, changing every term $[E_p]$ into its symbolic equivalent $[E]^p$, see Eq. (5), $[E]^{n-m}$ is seen to be a factor in every term of series (13), which may, therefore, be symbolically expressed—

$$\left.\begin{aligned}[E_n^m] &= [E_{n-m}].\{[E]+1\}^m \\ &= [E_{n-m}].E_m, \text{ (See Eq. 6).}\end{aligned}\right\} \ldots (14).$$

Hence also, by changing m into $(n-m)$—

$$\left.\begin{aligned}[E_n^{n-m}] &= [E_m].\{[E]+1\}^{n-m} \\ &= [E_m].E_{n-m}, \text{ (See Eq. 6).}\end{aligned}\right\} \ldots (15).$$

Again changing $[E]$ into its equivalent $(E-1)$, by Eq. (10), and interpreting the result by Eq. (8).

$$[E_n^{n-m}] = (E-1)^m.E_{n-m}$$

$$= E_n - \frac{m}{1}.E_{n-1} + \frac{m(m-1)}{1.2}.E_{n-2} - \ldots + (-1)^r.\frac{\lfloor m}{\lfloor r . \lfloor m-r}.E_{n-r} + \ldots + (-1)^{m-1}.\frac{m}{1}.E_{n-m+1} + (-1)^m.E_{n-m}. \quad (16).$$

Formulæ (13) and (16) furnish the means of calculating $[E_n^m]$ or $[E_n^{n-m}]$ in terms of $[E]$ or E respectively. The former is preferable if $m < n \div 2$, and the latter if $m > n \div 2$.

The following particular instances of these expansions may be recorded for reference :—

$$\left.\begin{aligned}[E'_n] &= [E_n] + [E_{n-1}]; & [E_n^{n-1}] &= E_n - E_{n-1} \\ [E''_n] &= [E_n] + 2[E_{n-1}] + [E_{n-2}]; & [E_n^{n-2}] &= E_n - 2E_{n-1} + E_{n-2} \\ [E'''_n] &= [E_n] + 3[E_{n-1}] + 3[E_{n-2}] + [E_{n-3}]; & [E_n^{n-3}] &= E_n - 3E_{n-1} + 3E_{n-2} - E_{n-3}\end{aligned}\right\} (17).$$

The following relations between successive values of $[E_n^m]$ and also $[E_n^{m-n}]$ might be obtained by induction from the above equations, viz., that—

$$\left.\begin{aligned}[E_n^m] &= [E_n^{m-1}] + [E_{n-1}^{m-1}] \\ [E_n^{n-m}] &= [E_n^{n-m+1}] - [E_{n-1}^{n-m}]\end{aligned}\right\} (18).$$

but are more readily obtained in a *general* manner by symbolic work, thus—

$$[E_n^{m-1}] + [E_{n-1}^{m-1}] = [E_{n-m+1}] . E_{m-1} + [E_{n-m}] . E_{m-1} \text{ by Eq. (14).}$$
$$= [E_{n-m}] . E_{m-1} . \{ [E] + 1 \} \text{ by Eq. (5).}$$
$$= [E_{n-m}] . E_m = [E_n^m] \text{ by Eq. (10, 7, and 14).}$$
$$[E_n^{n-m+1}] - [E_{n-1}^{n-m}] = [E_{m-1}] . E_{n-m+1} - [E_{m-1}] . E_{n-m} \text{ by (15).}$$
$$= [E_{m-1}] . E_{n-m} . (E - 1) \text{ by Eq. (7).}$$
$$= [E_m] . E_{n-m} = [E_n^{n-m}] \text{ by Eq. (10, 5, \& 15).}$$

V. *Addendum to Problems* (III.) *and* (IV.)

The expressions (11) and (16) for $[E_n]$ and $[E_n^{n-m}]$ in terms of E obtained by a *symbolic* inversion of the formulæ (4) and (13) previously obtained for E_n and $[E_n^m]$ in terms of $[E_n]$ may also be obtained by *algebraic* inversion of the same formulæ, but the process is very tedious. They may also be obtained *directly* from the properties of determinants by establishing expressions for $[\Delta]$ and $[\Delta^{n-m}]$ in terms of Δ inverse to the expressions (3) and (12) used in the text.

The required expressions are easily seen to be—

$$[\Delta] = \Delta - \Sigma \left\{ a_{pp} . \frac{d\Delta}{da_{pp}} \right\} + \Sigma \left\{ a_{pp} a_{qq} . \frac{d^2\Delta}{da_{pp} . da_{qq}} \right\} -$$
$$\Sigma \left\{ a_{pp} a_{qq} a_{rr} . \frac{d^3\Delta}{da_{pp} . da_{qq} . da_{rr}} \right\} +$$
$$+ \ldots + \ldots + (-1)^n . (a_{11} a_{22} a_{33} \ldots a_{nn}) \ldots (19).$$

$$[\Delta^{n-m}] = \Delta - \Sigma \left\{ a_{pp} . \frac{d\Delta}{da_{pp}} \right\} + \Sigma \left\{ a_{pp} a_{qq} . \frac{d^2\Delta}{da_{pp} . da_{qq}} \right\}$$
$$\ldots + (-1)^m . \Sigma \left\{ a_{11} a_{22} a_{33} \ldots a_{mm} . \frac{d^m\Delta}{da_{11} . da_{22} . da_{33} \ldots da_{mm}} \right\} (20).$$

Equations (11) and (16) may be derived from Eq. (19) and (20) respectively by considerations precisely similar to those used in obtaining Eq. (4) and (13) from Eq. (3) and (12) respectively in the text.

The relations established in Problems (III.) and (IV.) between E_n, $[E_n]$, and $[E_n^m]$ are evidently derived in a manner which shows them to be *generally* true of all determinants whatever which are related to one another *similarly* to those styled Δ, $[\Delta]$, $[\Delta^m]$, *i.e.*, *differing only in their leading constituents* (those of Δ being all finite, those of $[\Delta]$ all zero, those of $[\Delta^m]$ being m finite, and the rest zero).

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VI. *Application to Ordinary Determinants.*

Substituting $E^p = \lfloor p$, (Eq. 2) into Eq. (11), there results—

$$[E_n] = \lfloor n . \left\{ 1 - \frac{1}{\lfloor 1} + \frac{1}{\lfloor 2} - \frac{1}{\lfloor 3} + \ldots + \frac{(-1)^r}{\lfloor r} + \right\} \ldots \\ \ldots\ldots + \frac{(-1)^{n-1}}{\lfloor n-1} + \frac{(-1)^n}{\lfloor n} \Bigg\} \ldots \\ = \lfloor n . \Sigma_0^n \frac{(-1)^x}{\lfloor x} \ldots\ldots\ldots\ldots \Bigg\} \quad (21).$$

A relation between three successive values of $[E_n]$ may be thus found by Eq. (21)—

$$[E_{n-1}] + [E_{n-2}] = \lfloor n-1 . \Sigma_0^{n-1} \frac{(-1)^x}{\lfloor x} + \lfloor n-2 . \Sigma_0^{n-2} \frac{(-1)^x}{\lfloor x}$$

$$= \lfloor n-1 . \frac{(-1)^{n-1}}{\lfloor n-1} + \left\{ (n-1)+1 \right\} . \lfloor n-2 . \Sigma_0^{n-2} \frac{(-)^{1x}}{\lfloor x}$$

$$\therefore (n-1) . \left\{ [E_{n-1}] + [E_{n-2}] \right\} = (-1)^{n-1} . (n-1) + \lfloor n . \Sigma_0^{n-2} \frac{(-1)^x}{\lfloor x}$$

$$= \lfloor n . \left\{ \frac{(-1)^n}{\lfloor n} + \frac{(-1)^{n-1}}{\lfloor n-1} + \Sigma_0^{n-2} \frac{(-1)^x}{\lfloor x} \right\}$$

$$= \lfloor n . \Sigma_0^n \frac{(-1)^x}{\lfloor x}$$

$$= [E_n], \ldots \text{by Eq. (20)} \ldots (22).$$

This relation (22) between three successive values of $[E_n]$ may also be thus obtained *directly* :—

Since the leading constituents of $[\Delta]$ are all zero (by definition)—

$$\therefore [\Delta] = \frac{1}{n} . \Sigma \left\{ a_{yz} . \frac{d[\Delta]}{da_{yz}} \right\} \ldots\ldots\ldots (23).$$

in which equation y, z take all positive integral values (except equal values) from 1 to n. Now $\frac{d[\Delta]}{da_{yz}}$ is easily seen to be a determinant of $(n-1)$ rows containing $(n-2)$ of the leading (evanescent) constituents of the original determinant $[\Delta]$, and no *two* of these in the same row or column. These $(n-2)$ constituents may by change of order of rows or columns of the determinant $\frac{d[\Delta]}{da_{yz}}$ be all brought into its leading diagonal without altering its *numerical* value (the only alteration being of sign). It follows that the number of elements in $\frac{d[\Delta]}{da_{yz}}$ is the same as in a determinant of $(n-1)$ rows with only *one* finite leading constituent, which number (by notation of Problem IV.) is $[E'_{n-1}]$.

Further, the number of terms in the sum in Result (23) is clearly the same as the number of constituents of type a_{yz} in $[\Delta]$, *i.e.* (n^2-n), see par. 4, Problem I.

Hence, since $[E_n]$ is (by the notation) the number of elements in $[\Delta]$, it follows from (23) that—

$$[E_n] = \frac{1}{n}.(n^2-n).[E'_{n-1}]$$

$$=(n-1).\{[E_{n-1}]+[E_{n-2}]\}, \text{ by Eq. (17) . . (22).}$$

Thus, the value of $[E_n]$ may be calculated for *successive* values of n by formula (22) from the known values of $[E_1]$, $[E_2]$, &c., or may be directly calculated from the series (21).

It will be useful to record a few values of $[E_n]$ for reference, thus—

$$\left.\begin{array}{l}[E_1]=0,\ [E_2]=1,\ [E_3]=2,\ [E_4]=9,\ [E_5]=44,\\ [E_6]=265,\ [E_7]=1854,\ [E_8]=14{,}833,\\ [E_9]=133{,}496,\ [E_{10}]=1{,}334{,}961.\end{array}\right\} \text{. . (24).}$$

Corollary. Substituting for $[E_n]$ from Eq. (21) into Eq. (4) and (2), and separating the symbols of operation and quantity—

$$\left.\begin{array}{l}\underline{|n}=E_n=\underline{|n}.\{\Sigma_o^n+\frac{1}{\underline{|1}}.\Sigma_o^{n-1}+\frac{1}{\underline{|2}}\Sigma_o^{n-2}+\ \ldots\\ \qquad+\frac{1}{\underline{|r}}.\Sigma_o^{n-r}+\ \ldots\frac{1}{\underline{|n-1}}.\Sigma_o^1+\frac{1}{\underline{|n}}.\Sigma_o^0\end{array}\right\}.\frac{(-1)^x}{\underline{|x}},$$

from which may be deducted the two sums—

$$\Sigma_o^n\frac{1}{\underline{|x}}.\Sigma_o^{n-x}\frac{(-1)^x}{\underline{|x}}=1=\Sigma_o^n\frac{1}{\underline{|n-x}}\Sigma_o^x\frac{(-1)^x}{\underline{|x}} \quad . \ . \ . \ . \ (25).$$

It is easy to see that all the terms of the series (21) for $[E_n]$ are even integers except the two last, which are $(-1)^{n-1}(n-1)$, so that $[E_n]$ will be an integer, and odd or even according as n is even or odd.

VII. *Number of Elements which are Products of $n\div 2$ Pairs of Conjugate Constituents in a Determinant whose Leading Constituents Vanish.*

This problem is a preliminary to the problem of finding the number of elements in a symmetric determinant.

By "conjugate constituents" are meant pairs of type a_{yz}, a_{zy}.

The type of element in question is—

$$\{(a_{pq}.a_{qp}).(a_{rs}.a_{sr}) \ . \ . \ . \ . \ . \ (a_{yz}.a_{zy}.)\}$$

containing $n\div 2$ products of pairs of conjugate constituents, such as $(a_{yz}.a_{zy})$. This element may be separated into two conjugate factors, viz. $(a_{pq}.a_{rs}. \ . \ . \ . \ a_{yz}).(a_{qp}.a_{sr}. \ . \ . \ . \ a_{zy})$

either of which involves the other, and *each* of which is the product of $n \div 2$ constituents involving *all* the suffixes *without repetition*. Hence the number of such elements is the same as the number of ways in which a product of $n \div 2$ constituents can be formed involving *all* the n suffixes *without repetition*.

Let S_n be the number of products containing n suffixes *without repetition*.

Now the number of constituents containing any particular suffix p is clearly $(n-1)$, for these constituents are of type A_{py}, where y has every value from 1 to n, *excepting* p. Also for *every* such constituent as a_{py}, there are $(n-2)$ suffixes remaining to form the remaining $\left(\frac{n}{2}-1\right)$ constituents required to form the complete product of $n \div 2$ constituents. Further, these $(n-2)$ suffixes can be arranged into the required product of $\left(\frac{n}{2}-1\right)$ constituents of the requisite type in S_{n-2} ways (by preceding notation).

Hence $S_n = (n-1).\ S_{n-2}$.

Similarly $S_{n-2} = (n-3).S_{n-4}$, and so on.

Hence
$$\left.\begin{aligned} S_n &= (n-1).S_{n-2} = (n-1).(n-3)S_{n-4} = \ . \ . \ . \\ &= (n-1).(n-3).(n-5) \ . \ . \ . \ 7.5.3.S_2 \ . \ . \\ &= (n-1).(n-3).(n-5) \ . \ . \ . \ 7.5.3.1 \ . \ . \ . \end{aligned}\right\} (26).$$

since obviously when $n=2$, there is only one pair of conjugate constituents (viz., a_{12}, a_{21}), so that $S_2 = 1$

$$\therefore S_n = \frac{n(n-1)(n-2)(n-3)(n-4) \ . \ . \ . \ . \ 7.6.5.4.3.2.1}{n. \quad (n-2) \quad (n-4). \ . \ . \ . \ . \quad 6.4.2}$$

$$= \frac{\lfloor n}{2^{\frac{n}{2}}.\lfloor \frac{n}{2}}, \text{ where } n \text{ is an } \textit{even} \text{ integer.} \qquad \therefore \ . \ (27).$$

It is obvious that, if n be an *odd* number, the proposed product of $n \div 2$ pairs of conjugate constituents could not be formed, *i.e.* that *no* elements exist of type proposed.

$\therefore S_n = o$, when n is an *odd* integer . . . . . (28).

A few values of S_n may be recorded for reference, and note that S_n is always an odd integer (when n is even), being itself the product of odd integers, Eq. (26).

$S_0 = 1$, $S_2 = 1$, $S_4 = 3$, $S_6 = 15$, $S_8 = 105$, $S_{10} = 945$ . . . (29).

VIII. *Number of Elements in a Symmetric Determinant.*

Modify the preceding notation in capital letters for ordinary determinants by using the corresponding small letters with like meanings for symmetric determinants.

Thus $\Delta, [\Delta], [\Delta^m], E_n, [E_n], [E^m_n]$ become—

$$\delta, [\delta], [\delta^m], e_n, [e_n], [e^m_n].$$

All the relations between $E_n, [E_n], [E^m_n]$ established in Problems (III.) and (IV.) obtain also between e_n, $[e_n]$, $[e^m_n]$, having been established in a general manner, as properties common to all determinants.

The number of elements $[e_n]$ in the symmetric determinant $[\delta]$, whose leading constituents vanish, will first be investigated.

Number of Elements in a Symmetric Determinant whose Leading Constituents are Zero.

In the *ordinary* determinant $[\Delta]$ whose leading constituents vanish, the elements may be divided into two classes:—

(1). Of type $\{(a_{pq}.a_{\ p}).(a_{rs}a_{sr.}) \ . \ . \ . \ (a_{yz.}a_{zy})\}$ consisting of the product of $n \div 2$ pairs of *conjugate* constituents (such as $(a_{yz.}a_{zy})$ only. This number has been investigated in Problem (VII.), and denoted by S_n.

(2). Of type—

$$\{(a_{pq.}a_{qp}).(a_{rs}a_{sr}) \ . \ . \ . \ (a_{yz.}a_{zy})\} \times \{a_{fg.}a_{gh.}a_{hi.} \ . \ . \ . \ .a_{mf.}\},$$

consisting of the product of r pairs of *conjugate* constituents (such as $a_{yz.}a_{zy}$), and $(n-2r)$ other constituents (containing *no* conjugate pair; that is to say, consisting in part at least of the product of constituents containing *no* conjugate pair. The number of this type is clearly $\{[E_n]—S_n\}, [E_n]$ being (by the notation) the whole number of elements in the determinant $[\Delta]$.

In the corresponding *symmetric* determinant $[\delta]$, in which (by definition) $a_{yz} = a_{zy}$, these classes become—

(1). Of type $\{(a_{pq.}a_{rs.} \ . \ . \ . \ . \ a_{yz}\}^2$, each element being the square of the product of $n \div 2$ constituents, *without repetition of any suffix*. Also the number of these is clearly the same, viz., S_n as in the corresponding ordinary determinant $[\Delta]$.

(2). Of type $\{a_{pz.}a_{rs.} \ . \ . \ . \ . \ a_{yz}\}^2 \times \{a_{fg.}a_{gh.}a_{hi.} \ . \ . \ . \ a_{mf}\}$ consisting of the product of the square of the product of r constituents, *without repetition of any suffix*, and the product of $(n—2r)$, other constituents containing no conjugate pair, which therefore involves the remaining $(n—2r)$ suffixes in a cyclic change, *i.e.*, *each occurring twice*.

Now in the ordinary determinant $[\Delta]$, elements of this type (2) occur in pairs, *i.e.*, for *every* product of a particular set of conjugate constituents, as $\{(a_{pq.}a_{qp}).(a_{rs.}a_{sr.}) \ . \ (a_{yz.}a_{zy})\}$,

there is a *pair of conjugate products* of $(n-2r)$ other constituents, viz. $\{a_{fg}.a_{gh}\,a_{hi}.\ldots.a_{mf}\}$ and $\{a_{fm}.\ldots.a_{ih}.a_{hg}.a_{gf}.\}$, so that the type of *the sum of a pair* of such conjugate elements is $\{(a_{pq}.a_{qp}).(a_{rs}\,a_{sr})\ldots(a_{yz}a_{zy}.)\}\times[\{a_{fg}.a_{gh}.a_{hi}\ldots a_{mf}\}+\{a_{fm}.\ldots a_{ih}.a_{hg}.a_{gf}\}]$, which pair reduces in the symmetric determinant $[\delta]$ to a single element of type—

$$2\{a_{pq}.a_{rs}.\ldots.\ldots a_{yz}\}^2.[a_{fg}.a_{gh}.a_{hi}.\ldots.\ldots a_{mf}.]$$

since by definition $a_{yz}=a_{zy}$. The number of elements of this type in the symmetric determinant $[\delta]$ is therefore one-half that in the ordinary determinant $[\Delta]$, *i.e.* is $\frac{1}{2}\{[E_n]\{-S_n\}$,

Adding the number of both classes together, there results—

$$[e_n]=S_n+\tfrac{1}{2}\{[E_n]-S_n\}=\tfrac{1}{2}\{[E_n]+S_n\}\ldots\ldots\ldots(30).$$

substituting for $[E_n]$ and S_n from formulæ (21), (27), (28),

$$\left.\begin{aligned}[e_n]=\tfrac{1}{2}\ [E_n] &= \frac{\lfloor n}{2}.\Sigma_0^n\frac{(-1)^x}{\underline{x}} && \text{when } n \text{ is odd}\\ [e_n]=\tfrac{1}{2}\{[E_n]+S_n\} &= \frac{\lfloor n}{2}.\left\{\Sigma_0^n\frac{(-1)^x}{\underline{x}}+\frac{1}{2^{\frac{n}{2}}.\underline{\frac{n}{2}}}\right\} && \text{when } n \text{ is even}\end{aligned}\right\}(31).$$

Also, since $[E_n]$ is known to be an even integer when n is odd, and an odd integer when n is even (see Problem VI.), and since also S_n is an odd integer when n is even, it is easily seen from (31) that $[e_n]$ is always an integer (as of course it should be).

A relation between three successive values of $[e_n]$ may be deduced from that between three successive values of $[E_n]$, see Eq. (22)—

Thus $[E_n]=(n-1).\{[E_{n-1}]+[E_{n-2}]\}$

$$\therefore\ 2[e_n]-S_n^2=(n-1).\{2[e_{n-1}]+2[e_{n-2}]-S_{n-1}-S_{n-2}\},\ \text{by Eq. (30).}$$

And when n is odd—

$$S_n=0,\ S_{n-1}=\frac{\lfloor n-1}{2^{\frac{n-1}{2}}.\underline{\frac{n-1}{2}}},\ S_{n-2}=0,\ \text{by (27), (28).}$$

And when n is even $S_n=(n-1).S_{n-2}$, $S_{n-1}=0$, by (26), (28).

$$\left.\begin{aligned}\therefore\ [e_n]&=(n-1).\{[e_{n-1}]+[e_{n-2}]\}-\tfrac{n-1}{2}.S_{n-1}\\ &\text{when } n \text{ is odd}\\ [e_n]&=(n-1).\{[e_{n-1}]+[e_{n-2}]\}\\ &\text{when } n \text{ is even}\end{aligned}\right\}\ldots\ldots(32).$$

Thus the value of $[e_n]$ may be calculated for *successive*

values of n by formula (32), from the known values of $[e_1]$, $[e_2]$, &c., or may be directly calculated from formulæ (31).

It will be useful to record a few values of $[e_n]$ for reference—

$$\left.\begin{array}{r}[e_0]=1, [e_1]=0\,[e_2]=1, [e_3]=1, [e_4]=6, [e_5]=22,\\ [e_6]=140, [e_7]=927, [e_8]=7469, [e_9]=66{,}748,\\ [e_{10}]=667{,}953\end{array}\right\}\ldots\ldots(33).$$

IX. *Numbers of Elements in a Symmetric Determinant.*

This may easily be calculated from the known number $[e_n]$ of elements in the symmetric determinant $[\delta]$, whose leading constituents are zero, by help of the relation between e and $[e]$ (see Eq. 6).

Thus $e_n=(1+[e])^n$

$$=1+\frac{n}{1}[e_1]+\frac{n(n-1)}{1.2}[e_2]+\ldots+\frac{\lfloor n}{\lfloor r.\,\lfloor n-r}[e_r]+\ldots$$
$$+\frac{n}{1}[e_{n-1}]+[e_n]\ldots(34).$$

It will be useful to record a few values of e_n for reference, thus—

$$\left.\begin{array}{r}e_0=1,\ e_1=1,\ e_2=2,\ e_3=5,\ e_4=17,\ e_5=73,\ e_6=398,\\ e_7=2636,\ e_8=20{,}542,\ e_9=182{,}750,\ e_{10}=1{,}819{,}148\end{array}\right\}\ldots(35).$$

X. *Number of Elements in a Symmetrical Determinant, out of whose Leading Constituents only m are Finite.*

This may be easily calculated, either directly from the relations (13) and (16), or for successive values of n from the relations (18) which have established for all determinants. Thus changing E to e—

$$[e_n^m]=[e_n]+\frac{m}{1}.[e_{n-1}]+\frac{m(m-1)}{1.2}.[e_{n-2}]+\ldots$$
$$+\frac{\lfloor m}{\lfloor r.\,\lfloor m-r}.[e_{n-r}]+\ldots+\frac{m}{1}.[e_{n-m+1}]+[e_{n-m}]\ldots(36).$$

$$[e_n^{n-m}]=e_n-\frac{m}{1}.e_{n-1}+\frac{m(m-1)}{1.2}.e_{n-2}+\ldots+\frac{(-1)^r\,\lfloor m}{\lfloor r.\,\lfloor m-r}.e_{n-r}+\ldots$$
$$+(-1)^{m-1}\frac{m}{1}.e_{n-m+1}+(-1)^m e_{n-m}\ldots(37).$$

$$[e_n^m]=[e_n^{m-1}]+[e_{n-1}^{m-1}],\text{ and }[e_n^{n-m}]=[e_n^{n-m+1}]-[e_{n-1}^{n-m}]\ldots(38).$$

On account of the great use of symmetric determinants in modern geometry, it will be useful to record the values of $[e_n^m]$ in a few cases. Thus, observing that $[e_n^0]=[e_n]$, and that $[e_n^n]=[e_n]$, (by notation)—

Table of Values of $[e_n^m]$ ..... (39).

n	m										
	o	i.	ii.	iii.	iv.	v.	vi.	vii.	viii.	ix.	x.
0	1										
1	0	1									
2	1	1	2								
3	1	2	3	5							
4	6	7	9	12	17						
5	22	28	35	44	56	73					
6	140	162	190	225	269	325	398				
7	927	1067	1229	1419	1644	1913	2238	2636			
8	7469	8396	9463	10692	12111	13755	15668	17906	20542		
9	66748	74217	82613	92076	102768	114879	128634	144302	162208	182750	
10	667953	734701	808918	891531	983607	1086375	1201254	1329888	1474190	1636398	1819184

XI. *Number of Elements in a Skew Symmetric Determinant.*

Denote the number of elements in a *skew symmetric* determinant of n rows by $[\varepsilon_n]$, the brackets being used to preserve the analogy with previous notation for determinants whose leading constituents are zero.

It is shown (Salmon, Art. 37) that every skew symmetric determinant of odd order vanishes; the number of its elements is therefore zero.

It is shown (Salmon, Art. 38, 39) that every skew symmetric determinant of even order is a perfect square, and may be expressed by $\{\Sigma(\pm a_{pq} \cdot a_{rs} \ldots \ldots a_{yz})\}^2$, *i.e.*, by the square of the sum of terms of type $(\pm a_{pq} \cdot a_{rs} \ldots . a_{yz})$, each of which is the product of $n \div 2$ constituents, involving *all* the suffixes *without repetition*. It has been shown (Problem VII.), that the number (S_n) of such products in a determinant whose leading constituents vanish (as is the case in a skew symmetric determinant, see Salmon, Art. 37) is $S_n = \lfloor n \div \left(2^{\frac{n}{2}} \cdot \left\lfloor \frac{n}{2} \right\rfloor \right)$.

Also, since the determinant is the square of S_n different terms, it follows that the number of its elements $[\varepsilon_n]$ is the same as the number of terms in the expanded square of the sum of S_n quantities.

$$\left.\begin{aligned} \therefore [\varepsilon_n] &= S_n + \left\{\begin{matrix}\text{(number of combinations of}\\ S_n \text{ things two together).}\end{matrix}\right. \\ &= S_n + \tfrac{1}{2} S_n \cdot (S_n - 1) \\ &= \tfrac{1}{2} S_n \cdot (S_n + 1), \\ &= \frac{\lfloor n \cdot (\lfloor n + 2^{\frac{n}{2}} \cdot \lfloor \frac{n}{2} \rfloor)}{2^{n+1} \cdot (\lfloor \frac{n}{2})^2} \end{aligned}\right\} \text{when } n \text{ is } \textit{even} \ldots . (40),$$

And $[\varepsilon_n] = 0$, when n is *odd*, (v. supra) .... (41).

Eq. (40) shows that $[\varepsilon_n]$ is always an integer (as it should be). It will be useful to record a few values of $[\varepsilon_n]$ for reference. Thus—

$$\left.\begin{array}{r}[\varepsilon_0]=1,\ [\varepsilon_2]=1,\ [\varepsilon_4]=6,\ [\varepsilon_6]=120,\ [\varepsilon_8]=5565,\\ [\varepsilon_{10}]=446{,}985\end{array}\right\}\ldots.(42).$$

XII. *Number of Elements in a Skew Determinant.*

Denote the number of elements in a skew determinant of n rows by ε_n. Then, since a skew symmetric determinant is a skew determinant whose leading constituents are zero, the relation between them is the same as between $[\Delta]$ and Δ, so that the relations between $[\varepsilon_n]$ and ε_n will be the same as those between $[E_n]$ and E_n demonstrated under Problems (III.) and (IV.) as common to all determinants. Thus, the values of ε_n may be calculated from Eq. (6), viz.:—

$$\varepsilon_n=(1+[\varepsilon]^n)$$
$$=1+\frac{n}{1}.[\varepsilon_1]+\frac{n(n-1)}{1.2}.[\varepsilon_2]+\ldots+\frac{\lfloor n}{\lfloor r.\lfloor n-r}.[\varepsilon_r]+\ldots$$
$$+\frac{n}{1}[\varepsilon_{n-1}]+[\varepsilon_n]\ldots.(43).$$

A few values of ε_n may be recorded for reference—

$$\left.\begin{array}{l}\varepsilon_0=1,\ \varepsilon_1=1,\ \varepsilon_2=2,\ \varepsilon_3=4,\ \varepsilon_4=13,\ \varepsilon_5=41,\ \varepsilon_6=226,\\ \varepsilon_7=1072,\ \varepsilon_8=9374,\ \varepsilon_9=60{,}968,\ \varepsilon_{10}=723{,}966\end{array}\right\}\ldots.(44).$$

It is also seen that if $[\varepsilon_n^m]$ denote the number of elements in a skew determinant out of whose leading constituents only m are finite, then changing E in Problem (IV.) into ε, all the relations demonstrated under Problem (IV.) between E_n, $[E_n]$, and $[E_n^m]$ are true between ε_n, $[\varepsilon_n]$, and $[\varepsilon_n^m]$, so that $[\varepsilon_n^m]$ may be calculated from the known ε_n, $[\varepsilon_n]$ by the formulæ of Problem (IV.).

XIII. *Number of Minors in a Determinant.*

By definition, a pth minor is formed by erasing p rows and p columns from the original, so that evidently:—

A pth minor is a determinant of $(n-p)$ rows and columns
A $(n-p)$th minor is a determinant of p rows and columns

Let ${}^nM_p$ be the number of pth minors that can be formed from a determinant of n rows. Then ${}^nM_{n-p}$ is the number of $(n-p)$th minors.

It is obvious that, in this notation, the minor of zero order ($p=0$) being the original determinant itself, and the minors of nth order being zero—

$${}^nM_0=1, \text{ and } {}^nM_n=1$$
in *all* determinants (which are finite) . . . . (45).

Now ${}^{n}C_{r}$ being the number of combinations of n things taken r together (as in Problem III.), it is clear that ${}^{n}C_{p}$ is the number of ways in which p rows can be selected out of n rows, also that ${}^{n}C_{p}$ is the number of ways in which p columns can be selected out of n columns. But ${}^{n}M_{p}$ is evidently the number of ways in which *any* p rows and *any* p columns can be selected *simultaneously* (for erasion) from the n rows and n columns in the determinant.

$$\therefore {}^{n}M_{p} = {}^{n}C_{p} \times {}^{n}C_{p} = ({}^{n}C_{p})^{2} = \left(\frac{\lfloor n}{\lfloor p \cdot \lfloor n-p}\right)^{2} \ldots . (46).$$

Eq. (46) shows that, as is also evident from the reasoning itself—

$$ {}^{n}M_{p} = {}^{n}M_{n-p} \ldots \ldots \ldots \ldots (47).$$

From the preceding reasoning, it may also be inferred that result (47) is a property common to all determinants whose minors are *all* finite (except in certain cases when these numbers ${}^{n}M_{p}$, ${}^{n}M_{n-p}$ are unequally reduced, in consequence of the constituents being so related as to produce equality among some of the minors).

As a particular case of Eq. (47), ${}^{n}M_{1} = {}^{n}M_{n-1}$, *i.e.*, "The first minors are the same in number as the constituents (these being actually the $n-1$th minors)."

XIV. *Number of Minors in a Symmetric Determinant.*

In *symmetric* determinants it is clear that there is only *one* way in which a particular leading minor (which is itself also a symmetric determinant) can be selected, but that any other minor can always be selected in *two* ways, *e.g.*, the *same* (non-leading) pth minor may be formed either by omitting a certain set of p rows and p columns from the original determinant, or by omitting the conjugate set of p columns and p rows. This amounts to saying that the *non-leading* minors occur in pairs of equal magnitude.

Now the number of leading pth minors being those minors which contain $(n-p)$ leading constituents of the original determinants in their own leading diagonals, is clearly equal to the number of ways in which $(n-p)$ constituents can be selected from the whole n leading constituents, *i.e.*, is equal to ${}^{n}C_{n-p}$ or ${}^{n}C_{p}$.

Also, the number of *non-leading* pth minors would in an *ordinary* determinant be (Problem XIII.) $\{({}^{n}C_{p})^{2} - {}^{n}C_{p}\}$, which reduces in a *symmetric* determinant to $\frac{1}{2}\{({}^{n}C_{p})^{2} - {}^{n}C_{p}\}$ for

the reasons above. Hence the whole number of pth minors is—

$$\left.\begin{aligned} {}^nM_p &= {}^nC_p + \tfrac{1}{2}\{({}^nC_p)^2 - ({}^nC_p)\} \\ &= \tfrac{1}{2}\,{}^nC_p\,({}^nC_p + 1), \text{ which is clearly an integer.} \\ &= \frac{\lfloor n}{2} \cdot \frac{\lfloor n + \lfloor p \,.\, \lfloor n-p}{(\lfloor p \,.\, \lfloor n-p)^2} \end{aligned}\right\} \ldots (48).$$

Since ${}^nC_p = {}^nC_{n-p}$, therefore in symmetric determinants—

$${}^nM_p = {}^nM_{n-p} \ldots\ldots\ldots (49).$$

On account of the great use of symmetric determinants in modern geometry, it will be useful to record some values of ${}^nM_p$ for reference.

N.B. In general

$$\left.\begin{aligned} {}^nM_0 &= 1 = {}^nM_n\,, \\ {}^nM_1 &= \tfrac{1}{2}n(n+1) = {}^nM_{n-1} \\ {}^nM_2 &= \tfrac{1}{8}n\,.\,(n-1)\,(n^2-n+2) = {}^nM_{n-2} \end{aligned}\right\} . (50).$$

Values of ${}^nM_p \ldots\ldots\ldots (51).$

n.	Value of p.										
	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1	1	1									
2	1	3	1								
3	1	6	6	1							
4	1	10	21	10	1						
5	1	15	55	55	15	1					
6	1	21	120	210	120	21	1				
7	1	28	231	630	630	231	28	1			
8	1	36	406	1596	2485	1596	406	36	1		
9	1	45	666	3570	8001	8001	3570	666	45	1	
10	1	55	1035	7260	22155	31878	22155	7260	1035	55	

XV. *Number of Minors in a Skew Symmetric Determinant.*

Note that all leading minors are themselves skew symmetric determinants, so that all leading minors containing an *odd* number of rows vanish (Salmon, Art. 38). Now a pth minor contains $(n-p)$ rows, and the number of *leading* pth minors in a symmetric determinant is in general ${}^nC_p = \dfrac{\lfloor n}{\lfloor p \,.\, \lfloor n-p}$ (see Problem XIV.). Hence, in a skew symmetric determinant, the number of *leading* pth minors is zero, or ${}^nC_p$ according as $(n-p)$ is odd or even. And the number of *non-leading* pth minors will be the same as in a symmetric determinant in general, viz., $\frac{1}{2}\,.\,\{({}^nC_p)^2 - {}^nC_p\}$. Hence, in a skew symmetric determinant—

$$\left.\begin{aligned} {}^{n}M_{p} &= \tfrac{1}{2}\,.\,{}^{n}C_{p}\,.\,({}^{n}C_{p}-1) = \frac{\lfloor n}{2}\cdot\frac{\lfloor n-\lfloor p\,.\,\lfloor n-p}{(\lfloor p\,.\,\lfloor n-p)^{2}}, \\ &\qquad\qquad \text{when } (n-p) \text{ is odd} \\ {}^{n}M_{p} &= \tfrac{1}{2}\,.\,{}^{n}C_{p}\,.\,({}^{n}C_{p}+1) = \frac{\lfloor n}{2}\cdot\frac{\lfloor n+\lfloor p\,.\,\lfloor n-p}{(\lfloor p\,.\,\lfloor n-p)^{2}}, \\ &\qquad\qquad \text{when } (n-p) \text{ is even} \end{aligned}\right\} \ldots (52).$$

These quantities are evidently both integers (as they should be). Eq. (47) is true of this class of determinants only when p and $(n-p)$ are both odd or both even, which cannot occur when n is odd, but always happens when n is even. Thus—

$$ {}^{n}M_{p} = {}^{n}M_{n-p}, \text{ when } n \text{ is even} \ldots\ldots (53).$$

The following relation obtains between two successive values of ${}^{n}M_{1}$, the *higher* value of n being an *even* number; so that $(n-p)=(n-1)$, an odd number, and $(\overline{n-1}-p)=(n-2)$, an even number.

$$\therefore {}^{n}M_{1}=\tfrac{1}{2}\,n\,.(n-1)=\tfrac{1}{2}(n-1).(\overline{n-1}+n)={}^{n-1}M_{1}, \text{ by (52)},$$
$$n \text{ being even} \ldots . (54).$$

Eq. (52) shows that, *in general*, Eq. (45) is true of this class of determinants only when finite, *i.e.*, only when of even order, thus—

$$\left.\begin{aligned} {}^{n}M_{o} &= 0 = {}^{n}M_{n}, \text{ when } n \text{ is odd.} \\ {}^{n}M_{o} &= 1 = {}^{n}M_{n}, \text{ when } n \text{ is even.} \end{aligned}\right\} \ldots\ldots\ldots (55).$$

It will be useful to record a few values of ${}^{n}M_{p}$ for this class of determinant. Thus—

Values of ${}^{n}M_{p}$ . . . . . (56).

n.	Value of p.										
	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1	0	0									
2	1	1	1								
3	0	6	3	0							
4	1	6	21	6	1						
5	0	15	45	55	10	0					
6	1	15	120	190	120	15	1				
7	0	28	210	630	595	231	21	0			
8	1	28	406	1540	2485	1540	406	28	1		
9	0	45	630	3570	7875	8001	3486	666	36	0	
10	1	45	1035	7140	22155	31626	22155	7140	1035	45	1

NOTICES OF BOOKS.

Darwinism and Design; or Creation by Evolution. By GEORGE ST. CLAIR, F.G.S., M.A.I.A., &c. London: Hodder and Stoughton. 1873.

WE have here yet another attempt at a reconciliation of theology with science; but it is one which differs in many respects from all that have gone before it. The doctrine of evolution, as explained by Spencer and Darwin, is accepted in its entirety, and no objection is made to the most extreme consequences which those authors deduce from it; but it is argued with much force and ingenuity that design, and the constant action of a Supreme Ruler, is not thereby rendered inconceivable or unnecessary. A condensed but exceedingly accurate and well-written account of the most recent views of evolution is given in the first part of the volume; and this is a great merit, seeing how incapable most theological writers are of avoiding either positive misrepresentation or a partial and one-sided statement of the teachings of evolutionists. The theological treatment of the question is, however, somewhat peculiar and heterodox, and we fear will not meet with a favourable acceptance from the religious world; and this may render Mr. St. Clair's book less generally useful in reconciling the modern Christian mind to the teachings of Darwin than it might otherwise have been. A short account of the author's mode of treating the subject, and of the peculiarities above referred to, may not be uninteresting.

Throughout the book we meet with expressions and arguments which show us that the Deity or Supreme Ruler spoken of by the author is not the being to whom those terms are applied either in philosophy or religion. It is not the "Absolute" of the philosophers; it is not the "Almighty" and "Omnipresent" deity of the Christian; but it is a being subject, like ourselves, to the laws of matter and motion,—having to recognise the "nature of things," but having infinite knowledge which enables him to make use of the universe and its "necessary laws" so as to work out his own purposes. This view, which appears to us an impossible or at least an imperfect one, seems to have been adopted owing to the supposed "inconceivability" of the creation of matter out of nothing—an inconceivability which vanishes to any one who can thoroughly grasp the conception of matter as being essentially a complex set of forces and nothing else. To hold that these forces are eternal and self-existent, and that they produce by their varied interactions all the forms of dead matter, while an omniscient mind—equally eternal and self-existent—finds itself face to face with this matter and these forces which it can neither destroy nor originate, but only guide, is surely to

multiply difficulties. That the "forces" which we know as "matter" are in some way dependent on the supreme mind appears to us the only alternative to pure materialism; and this view renders it perfectly conceivable that "matter" may "be made out of nothing," or may be again resolved into nothing by the withdrawal of the mental action which is the sole cause of its existence. But if we conceive the material universe to be thus the product of the supreme mind, we may equally believe that there is a mental or spiritual universe, of which we ourselves form a part, and that the former is the means by which the latter is developed with the greatest capacity for happiness and eternal progress. Now Mr. St. Clair's deity is just such a being as we might suppose to be the highest in our material universe, and who might be charged with utilising to the utmost the powers of that universe in developing mind. He would "not violate natural law, but work by means of it," and his work would be liable to those "incidental results" often temporarily painful, injurious, or useless, which are such a stumbling-block to the usual ideas of divine government. The slow process of development—first of systems, then of worlds, then of matter into complex forms and qualities, and lastly, of organisation and life—has probably its own high uses, of which we can form no adequate conception. It may help the development of higher intelligences than ourselves; it may be the only mode by which multiplied forms of those higher intelligences can be produced. At all events, it is the system of nature; and it is hardly likely that any other possible system would be more intelligible to beings like ourselves—produced by it and still forming part of it.

Having thus indicated how we think Mr. St. Clair's theory may be made more consistent and more comprehensive, we proceed to give a few examples of his style of illustration and mode of reasoning. The argument against design from the existence of rudimentary organs or traces of structures that were useful only in ancestral forms, is answered by supposing a town, in which one of the main water-pipes goes half a mile into the country, and then bends back again with various windings for no useful purpose. "We ask where is the wisdom of carrying the water through this mile of pipe when it might go by the short cut? Why waste the tubing, and waste the time, and do what has to be undone immediately, in sending the stream to a point from which there is no course but to return? On the supposition that the town was originally built as it now stands, every street and square having the position they now have, and not a house more or less—our objection is valid. But if we learn that the diverging bend of pipe follows the route of streets which formerly existed, and that although the shorter cut would now seem better, yet it would cost more to take up the old pipes from the long route and lay down pipes on the short route than could possibly be gained by the process, we see the wisdom of leaving the arrangement

as it is; and we read in the existence of the bend of pipe a page of the past history of the town."

To the objection as to the existence of carnivorous animals in all ages of the earth's history, it is well replied that evolution shows struggle and death to be absolutely necessary to advancement and to render possible the eventual birth and perfecting of man. It is also very forcibly argued that there are many direct marks of beneficence in nature. So far as we know, there was no absolute need for life to appear at all on the earth; or, when it appeared, for it ever to have advanced beyond the lower forms; or for the distinction of male and female ever to have arisen; or for the eye to have the capacity of distinguishing sensations of colour as distinct from light and shade; or for the ear to be attuned so admirably to vibrations of the atmosphere as to render music possible; or for the taste to be capable of delighting in such an endless variety of savours. When we look at the whole range of past and present life upon the globe, what an infinite amount of pure enjoyment has been derived from every one of these faculties and powers, so that the existence of pain, which is the necessary correlative of many of them, counts for nothing in the balance. Even that endless variety, which seems a first principle of the material universe, so absolutely universal is it, adds in an incalculable degree to our enjoyment. It alone enables us to appreciate beauty, and it is almost certain that we should receive no pleasure from any of our senses if there were not an ever-varying series of objects and properties to excite them to various degrees and kinds of action. The conception that these almost infinite possibilities of enjoyment have come into existence as a necessary result of certain self-existent laws of self-existent matter, and have therefore not been in any way foreseen or designed by any intelligence, is one which seems too improbable to be permanently held by any thinker who will carefully examine the evidence from this point of view.

The last chapter—on the Moral Aspects of Evolution—is very well written, and deserves careful consideration. We have only space to notice what is termed the origin of moral species. The world has ever persecuted its reformers and put its prophets to death. The best, the wisest, and the most unselfish men have often left no posterity to inherit their good qualities. How, then, has the world advanced morally and intellectually? Mr. St. Clair imputes it to the generative action of mind upon mind, a more powerful agent in spreading truth and goodness than hereditary transmission. Each great mind acts upon all those which are somewhat lower than itself, and tends to raise them to its own level. "The man in whom the higher truth or higher virtue is first found may be said to constitute a new moral 'species' or 'variety.' The men who are nearest to him in the points in which he is distinguished are the species from which he probably has sprung, and being nearest to him would require

least alteration in themselves to make them quite like him. The influence fitted to produce this alteration is the presentation of his peculiarities before them in the example of his life or sufferings, in his verbal teaching or his written works. These, therefore, are the 'conditions of the environment' which induce 'variation' in a number of individuals, and convert them into the new species; it is not that offspring are generated in the parental likeness, but one species is evolved from another. Thus we have the wonderful fact that a new moral species can create the conditions which will cause others to vary into its likeness—the highest moral life agrees with the lowest physical life in possessing a protoplasmic power of multiplying itself indefinitely by contact. Not only has Natural Selection transferred its action to the mind, but the environing conditions which occasion the mental variations before they are selected have also to a large extent become mental." But this does not, as Mr. St. Clair remarks, explain how the variations arise which give purer conceptions and higher impulses to some men than to all the rest of mankind; neither does it explain why these dangerous gifts, often bringing persecution and death to their possessors, should have such a marvellous power of spreading, and prove so fascinating to many, to whom they will in all probability bring no better fate. He concludes that there is no other explanation but that truth and goodness have an immutable beauty proper to themselves, attractive to minds and consciences capable of perceiving the true relations of things; and that this can only be looked upon as due to the great Fount of all things.

We can cordially recommend this book to all who take an interest in the wider bearings of the doctrine of evolution. The writer is thoroughly imbued with the spirit of his subject, and even the experienced student will find much that is suggestive in the way in which the facts of well-known writers are presented and discussed. Some of the greater philosophical difficulties are, it is true, avoided rather than overcome; but we nevertheless feel that the book is well calculated to diminish anti-Darwinian prejudice, and to help forward the reconciliation of science with religion.

The Conservation of Energy. Being an Elementary Treatise on Energy and its Laws. By Balfour Stewart, M.A., F.R.S., Professor of Natural Philosophy at the Owen's College, Manchester. London: Henry S. King and Co. 1874. Crown, 8vo. 180 pp.

The Doctrine of the Conservation of Energy, which was indicated in Mr. Justice Grove's work on the "Correlation of the Physical Forces" some thirty years ago, has been considerably developed since the exact determination of the relationship which

exists between heat and mechanical work. Professor Stewart has written an admirable treatise on Heat, and has elsewhere discussed the Conservation of Energy with consummate ability. We are not disappointed by this more comprehensive treatment of the subject. He tells us succinctly in the preface his mode of discussing the subject. He divides our knowledge of the universe into two branches: the one knowledge of it as a vast physical machine composed of atoms swimming in the luminiferous ether; the other, the laws which regulate the working of this machine; in other words, the laws of energy.

In the first chapter, energy is defined as "the power of overcoming obstacles, or of doing work," as instanced by a rifle bullet in motion. The work is to be measured by some unit, preferably the kilogramme for weight, and the metre for height; and by multiplying a weight raised by the vertical height through which it is raised, we get the work done in kilogrammetres. Next we have various examples of the change of energy of position into energy of motion, and finally into heat. The usual and satisfactory examples of the head of water, the bent cross-bow, and the wound up watch are adduced, and the advantages of energy of position are exemplified by happily comparing a water-mill and a windmill with a rich and poor man. In the one case we may turn on the water whenever it is most convenient for us, but in the other we must wait until the wind happens to blow. The former has all the independence of a rich man; the latter all the obsequiousness of a poor one. If we pursue the analogy a step further, we shall see that the great capitalist, or the man who has acquired a lofty position, is respected because he has the disposal of a great quantity of energy; and whether he be a nobleman or a sovereign, or a general in command, he is powerful only from having something which enables him to make use of the services of others. When the man of wealth pays a labouring man to work for him, he is in truth converting so much of his energy of position into actual energy, just as a miller lets out a portion of his head of water in order to do some work by its means." This (second) chapter continues with an account of the functions of machines, the conversion of motion of a mass into heat, and the nature of the motion called heat. The next chapter discusses the various kinds of energy; gravity, elastic forces, cohesion, chemical affinity, electricity, magnetism. The classification of elastic forces among the energies is unusual, and we have always regarded elasticity as a function of cohesion, not as due to any separate and distinctive force. Prof. Stewart speaks of the "force of elasticity," but is it not rather a *property* belonging to certain bodies under certain conditions than a force? It does indeed require energy to bend a bow, but is not that energy expended in partially overcoming the cohesion of the molecules in one direction, and in approximating the molecules against their molecular motion in another? A useful condensed list of

energies is given (pp. 78-82), and this is immediately followed by the "Law of Conservation." This law asserts that the sum of all the various energies of the universe is a constant quantity, or as Prof. Stewart puts it—

(A) + (B) + (C) + (D) + (E) + (F) + (G) + (H) = a constant quantity.

Not that any single one energy is constant in itself, for they are perpetually changing into each other, but that the sum of these variable quantities is a constant quantity. The fourth chapter is entirely devoted to an account of the transmutations of energy, and the fifth gives the history of the idea from the earliest times, and then discusses at some length the dissipation of energy.

In discussing the early atomic theories, Professor Stewart has omitted the claims of Kanada, a Hindu philosopher, whose atomic theory was not only more complete and philosophical than that of Leukippos and Demokritos, but was also much earlier. A very interesting account of this theory (too little known in this country) is given by Sir John Colebrooke in his admirable articles on the Philosophy of the Hindus (in the "Proceedings of the Asiatic Society"). The statement that Demokritos "was the originator of the doctrine of atoms" is also incorrect, even as regards Greek philosophy, because Demokritos took the idea, which he indeed extended, from Leukippos. Again, the idea of the ethereal medium pervading all space was originated by the Hindus long before the time of Aristotle, and we protest against the assertion that Aristotle "caught a glimpse of the idea of a medium," when we find his constant mention of the Αἰθήρ and remember that he introduced the very name for it which we now adopt. We claim for the ancients much more than our author is disposed to grant them: surely they possessed a very definite atomic theory, a fairly definite idea of an ethereal medium pervading space, an exact idea of the transformation of one kind of matter into another, through the intervention of some external principle of motion; and at an earlier date than all, a four-element theory, which we accept in a too literal sense, but which was philosophical and profound for those unexperimental ages. Professor Stewart next passes on to "Descartes, Newton, and Huyghens on a Medium." "In modern times, he writes Descartes, author of the vertical hypothesis . . . " (vertical should surely read vortical), but Anaxagoras of Klazomene conferred upon his νοῦς, which is essentially a mover of matter, the property of inducing the vortical motion of atoms; and of all modern philosophers, to our mind, Descartes has most drawn upon the ideas of the ancients in his Cosmogony. The historical portion of this chapter is very slight and insufficient in our opinion, but no doubt a longer historical survey would have occupied space required for other matters.

The theory of the dissipation of energy is indeed a startling one; we are perpetually converting work into heat, but it is impossible to reconvert all the heat produced into work again.

What must result? "The mechanical energy of the universe will be more and more transformed into universally diffused heat, until the universe will no longer be a fit abode for living beings." . . . . "If we could view the universe as a candle not lit, then it is perhaps conceivable to regard it as having been always in existence; but if we regard it rather as a candle that has been lit, we become absolutely certain that it cannot have been burning from eternity; and that a time will come when it will cease to burn. We are led to look to a beginning, in which the particles of matter were in a diffuse chaotic state, but endowed with the power of gravitation, and we are led to look to an end in which the whole universe will be one equally heated inert mass, and from which everything like life, or motion, or beauty, will have utterly gone away."

The final chapter discusses the position of life:—An animal is defined as a machine of a delicacy which is practically infinite, the condition or motions of which we are utterly unable to predict. And what is life? "Life is not a bully who swaggers out into the open universe, upsetting the laws of energy in all directions, but rather a consummate strategist, who, sitting in his secret chamber, before his wires, directs the movements of a great army." Prof. Stewart has surely misread a statement made by Rumford:—"It was seen that in order to do work," says our author, p. 163, "an animal must be fed; and, even at a still earlier period Count Rumford remarked that a ton of hay will be administered more economically by feeding a horse with it, and then getting work out of the horse, than by burning it as fuel in an engine." Rumford words are these:* . . . "Heat may thus be produced merely by the strength of a horse, and, in case of necessity, this heat might be used in cooking victuals. *But no circumstances could be imagined in which this method of procuring heat would be advantageous; for more heat might be obtained by using the fodder necessary for the support of the horse as fuel.*" This latter must be the right view of the case, for part of the energy derived from the consumed hay is dissipated in the very working of the horse's great muscular mechanism, and a part of the work done by the horse is dissipated as heat by the friction of the working parts of the machine which it moves, whether that machine be one for producing heat by friction, as in Rumford's experiment, or for any other purpose.

Prof. Stewart's work is interesting and very readable. We commend it to all readers, whether scientific or otherwise, who are desirous of learning the most recent ideas connected with the various transmutations of the different physical forces.

* "An Enquiry Concerning the Source of the Heat which is Excited by Friction." Read before the Royal Society, Jan. 25th, 1798. The italics are our own.

Contemporary English Psychology. Translated from the French of Th. Ribot. London: Henry S. King and Co. 1873. 8vo. 328 pp.

It is always a matter of considerable interest to know the light in which our intellectual work is regarded by those who are not our own countrymen. The natural bias which causes a man or a people to view the literary or philosophical production of a fellow-countryman as unsurpassed works is not present in foreign criticism. We know how eargely M. Taine's "Notes on England," and on English Literature, were received; and although without doubt this was partly due to the eminence of the man, the cause mentioned above had also much to do with it. We have a powerful school of Psychology in this country at the present time, and a comparison and differentiation of the views of the more prominent members of it is desirable and important.

Philosophy was, in the beginning, universal science; it treated of "the universality of things, the all." Then came a separation of one of its parts, mathematics, some two centuries after the time of Pythagoras. But, according to M. Ribot, the old philosophy of Plato and Aristotle is still the universal science:—Metaphysics follow physics, politics follow morals, physiology follows psychology. In the middle ages, medicine and alchemy separated from it, and in the eighteenth century physics. Then philosophy in its broadest sense began to lose its comprehensiveness: nature was wrested from it; God and man remained to it. Philosophy once included all things, "principles and consequences, causes and facts, general truths and results;" ultimately "it will be metaphysics and nothing more." It has been said that "metaphysicians are poets who have missed their vocation," and M. Ribot considers the assertion just, but we must venture to differ from him. For surely the precise, hard, logical mode of thought which the metaphysician must adopt; his cold, lifeless theories and harsh unyielding laws ill consort with that warm flow of imagination which spontaneously should burst from the poet. Hegel's logic may indeed "border on Faust;" but what a thoroughly metaphysical poem Faust is! If all poems were like Faust, then indeed the poet and the metaphysician would have much in common. And what of the end of all philosophy? Let us suppose all our questions concerning God, nature, and ourselves, finally answered. What would remain for human intelligence to do? This solution would be its death. All enquiring and active minds will be of Lessing's opinion on this point: "There is more pleasure in coursing the hare than in catching it." Philosophy will keep up its activity by its magical and deceiving mirage. Were it never to render any other service to human intelligence than that of keeping it always on the alert, of elevating it above a narrow dogmatism, by showing it that mysterious beyond which surrounds and presses upon it in every science, philosophy would do enough for it."

M. Ribot considers at considerable length the proper definition of the Science of Psychology (a word first introduced by Goclenius). He shows that, during the seventeenth century, the science of the soul was called metaphysics; and that, hence, metaphysics and psychology have many points of connection. In its widest sense, he considers that psychology embraces "all the phenomena of mind in all animals," or if we follow Mr. Stuart Mill, and make more exact divisions, we have *General Psychology*: the study of the phenomena of consciousness, sensation, thought, emotions, relations, &c., considered under their most general aspects. This embraces *Comparative Psychology*, and *Psychological Teratology*, or a study of anomalies and monstrosities. At the conclusion of his most interesting introduction, our author tells us that since the time of Hobbes and Locke, England has done most to forward Psychology.

Then follows the main part of the book: a condensation of the psychological systems of Hartley, James Mill, Herbert Spencer, Alexander Bain, G. H. Lewes, Samuel Bailey, and John Stuart Mill. Thus the survey extends over about a century, but is mainly confined to the last thirty years.

The agreement of these philosophers in regard to all main points in each other's systems is clearly shown. These main points may be briefly stated as follows:—(*a*). Psychology examines the facts of consciousness, and connects those facts by definite laws. (*b*). It deals with phenomena, not knowing the nature of the soul or mind. (*c*). It studies these phenomena (1) objectively by signs and actions which interpret them, and (2) subjectively by memory and reason. Consciousness consists of "a continuous current of sensations, ideas, volitions, feelings," &c.; it is made up of the perception of a difference, and the perception of a resemblance. Perceptions are internal conditions corresponding to external conditions. These and many other definitions are given in the concluding remarks, in a clear, crisp form, very readable and understandable, and quite divested of unnecessary technicalities. We feel assured that the work will be received with open arms by the largely increasing school of English psychologists.

Animal Locomotion; or Walking, Swimming, and Flying. With a Dissertation on Aëronautics. By J. Bell Pettigrew, M.D., F.R.S., F.R.S.E., Pathologist to the Royal Infirmary of Edinburgh. London: Henry S. King and Co. 1873. Crown 8vo. Illustrated. 264 pp.

This work belongs to the "International Scientific Series," five or six volumes of which, including Professor Stewart's "Conservation of Energy," have already appeared, and many more are announced. The object of the author is to explain various

difficult problems in animal mechanics, and to discuss some of his views concerning the possibility of flying. A somewhat long introduction treats of the various motions possible to different creatures. It is herein shown that walking, swimming, and flying are only modifications of each other. "Walking merges into swimming, and swimming into flying, by insensible gradations," and the various differences in the actions are due to the fact that the media of support differ in density, earth for walking, water for swimming, air for flying. The relation of these actions is well shown by the fact that birds and insects can perform them all, while a large number of creatures can both walk and swim. "The subject of flight has never until quite recently been investigated systematically or rationally, and as a result, very little is known of the laws which regulate it. If these laws were understood, and we were in possession of trustworthy data for our guidance in devising artificial pinions, the formidable Gordian knot of flight there is reason to believe could be readily untied." Thus early in the book (page 4) does our author introduce an evidently pet idea that artificial flight is a possibility. The introduction is continued with various discussions of the operations performed during walking, swimming, and flying; thus we are told that the extremities of animals act as pendulums during walking, and describe curves like a figure of 8, as also do the bodies of fish in swimming, and the wings of birds in flying. Dr. Pettigrew, indeed, claims the discovery of the figure-of-8 theory. In the succeeding part of the work this theory is applied to, and illustrated by, the progression of various birds, beasts, and fishes. Some beautiful original drawings are given to illustrate these motions; we may notice particularly those which illustrate the movements of the wings of the wasp and fly (pp. 139—141).

Passing on to the subject of aëronautics, our author shows the extreme difficulty of the problem of artificial flight to consist, among other things, in "(3rd) the great rapidity with which wings, especially insect wings, are made to vibrate, and the *difficulty* experienced in analysing their movements; (4th) the great weight of all flying things when compared with a corresponding volume of air; and (5th) the discovery of the balloon, which has retarded the science of aërostation, by misleading men's minds, and causing them to look for a solution of the problem by the aid of a machine lighter than the air and which has no analogue in nature." The flightists may now be divided into two classes:—1st, those who advocate the use of balloons; 2ndly, those who consider that weight greater than the air is essential. This second class has two divisions:—"(*a*) those who advocate the employment of rigid inclined planes driven forward in a straight line, or revolving planes (aërial screws); and (*b*) such as trust for elevation and propulsion to the vertical flapping of wings." Dr. Pettigrew's work, although it may not

appeal to a large number of readers, is very readable, and will certainly be a great boon to the members of the Aëronautical Society.

Fruits and Farinacea; the Proper Food of Man. By the late JOHN SMITH, of Malton. Manchester: John Heywood; London: F. Pitman. 1873. 112 pp. Crown 8vo.

THIS small work, which has been edited by Professor William Newman for the Vegetarian Society, contains the substance of a work bearing the same title first published in 1845. It is an essay on vegetarianism, and endeavours to prove that vegetables were the original, and are the natural and best food of man. That such diet was originally adopted by mankind the author tries to show by various quotations from Genesis and other early writings. In the second chapter proofs are derived from our organs; the teeth are said to be unsuited to the mastication of animal food; and the argument is forwarded by the alleged inappropriateness of our salivary glands, alimentary canal, stomach, colon, cæcum, and liver. We really begin to wonder how man can have lived for centuries on an omnivorous diet if all his organs are unsuitable for anything but a vegetable diet. A curious table is given in the third chapter, showing the various times which different substances take to digest, after Dr. Beaumont. The amount in each case is not mentioned,—presumably equal weights; if so, it is not to be wondered at that soft boiled rice should digest in one-third the time of beef or mutton. Surely the composition of the various kinds of food should be given, in order to enable one to form a just estimate. We select a few substances:—

	Hours.	Mins.
Rice, boiled soft	1	0
Tapioca, stale bread, milk	2	0
Apple dumpling	3	0
Potatoes and turnips boiled, butter	3	30
Venison	1	35
Turkey	2	30
Boiled pork, hard-boiled eggs	3	30
Salt pork, boiled	4	30
Veal, roasted	5	30

This table is surely no great support to our author's argument, when we find that venison takes a shorter time to digest than tapioca, bread, cabbage, and milk, while boiled potatoes and turnips take longer than beef and mutton, and actually as long as that notoriously indigestible substance, boiled pork. Among other things, an attempt is made to prove that vegetable diet is "favourable to the moral state;" the use of wine is said to follow the stimulus of animal food. Noah drank wine and became

drunken soon after receiving permission to eat animal food; Jacob, when he brought his father the savoury mess of pottage, likewise brought wine. "Again," says Mr. Smith, "carnivorous animals are ferocious; the herbivorous are gentle, sociable, and playful." But, we would ask, can anything be more "sociable and playful" than a dog or a cat, anything more ferocious than a wild bull? Those who have seen wild horses fight in the prairies will class the horse with the bull. We cannot discuss such arguments as these; a similar mode of reasoning to that employed by Mr. Smith could be made to prove that black is white. This book appeals to a small class of persons; that it will convince anyone that vegetarianism is better than our present system we confidently doubt. We have been unable to find a trace of sound logic or convincing argument in the whole book, and are more than ever assured that our omnivorous diet is the right one.

Geology. By ARCHIBALD GEIKIE, LL.D., F.R.S., Director of the Geological Survey of Scotland. Illustrated. London: Macmillan and Co. 1874. 18mo. 130 pp.

THIS small volume forms the fifth of Messrs. Macmillan's Science Primers, and immediately follows the Physical Geography Primer, by the same author. The first of the series, by Professor Huxley, has not yet appeared, and is somewhat eagerly expected, as it forms an introduction to the whole series, and will without doubt discuss the modes and advantages of elementary science teaching. The author of the book before us is well known as an eminent geologist, and there is nothing to be said about his book in the way of criticism. The arrangement is clear and good; the subject-matter treats of sedimentary rocks, igneous rocks, and "organic rocks," that is, rocks consisting of the remains of plants and animals,—such as coal, chalk, and encrinitic limestone. At the conclusion we have various paragraphs relating to the crust of the earth considered as a whole, to prove that it has been upheaved and depressed at different epochs, which actions have produced tilting, crumpling, and breaking of the crust. We find here, too, a section on the origin of mountains. A few good illustrations help the beginner to realise the various descriptions.

A Phrenologist Amongst the Todas, or the Study of a Primitive Tribe in South India; History, Character, Customs, Religion, Infanticide, Polyandry, Language. By WILLIAM MARSHALL, Lieutenant-Colonel of Her Majesty's Bengal Staff Corps. London: Longmans, Green, and Co. 1873.

THE native inhabitants of the Indian peninsula may be broadly divided into two great races,—the Aryans, inhabiting the whole

of the northern and western plains,—the Dravidians, occupying the central and southern districts. The first comprehend all the more civilised peoples—the Mahomedans and Hindoos; the second are in various lower stages of civilisation, and are mostly pagans. Besides these there are a number of obscure tribes, such as the Kols, whose language is allied to some dialects of Pegu, and the Pariahs and other servile castes, who may probably represent a remnant of some of the earliest savage inhabitants of the country. The Aryans belong to the great Aryan or Indo-Germanic race, and their language no less than their physical features allies them to the highest European peoples. The Dravidians, on the other hand, are more related to the Mongolian races; and their nearest affinity has been traced by language to the Finns and Lapps far in the north-western corner of Europe. Philologists look upon these Dravidians as a much older people than the Aryans. They probably once spread over a large portion of Europe and Asia, and entered India from the north and north-west, occupying the country, and exterminating, or making slaves of, the rude aborigines. At a later epoch the higher Aryan type was developed, and drove out the Dravidians from all the more fertile parts of Europe. This energetic people were the parents of the Celts in the west, of the Germans and Slavonians in mid-Europe, and of the Sanscrit-speaking Aryans in the east; and these latter entered India from the north-west, and took the place of the Dravidians in all the more fertile and accessible districts as these latter had taken the place of the older aborigines.

The Dravidians of India now form eight tribes or nations, speaking distinct though allied languages. These are the Tamil, Telugu, Kanarese, Malayâlam, Tuluva, Toda, Gônd, and Khond, the first five belonging to more civilised peoples possessing a written character, while the three last are spoken by comparatively savage tribes. The smallest of these tribes, the Todas, is confined to the plateau of the Nilagiri Mountains, and consists of about 700 individuals. They formerly practised infanticide as an institution, and the result was that they were rapidly becoming extinct; but, owing to the influence of the Indian Government, this has been discontinued for many years, and they now increase in population with tolerable rapidity. These Todas are, in many respects, one of the most interesting and peculiar tribes in the world; and every student of man is indebted to Colonel Marshall for the careful study he has made of their whole physical, mental, and moral nature, and for the well-illustrated and instructive volume in which he gives both his detailed observations and the conclusions which he draws from them.

We will endeavour to sketch in outline the most curious features of Toda life, in the hope that we may induce many of our readers to go for fuller information to the book itself.

XUM

The Todas live in very small village communities of from 20 to 30 persons. Their houses, or huts, two or three together, and sometimes all under one roof, are low and somewhat of an inverted boat-shape, with very low doors (only about three feet high), and no windows. Attached to every village is a cattle-pen, and a separate building, which comprises the dairy and the dairyman's abode. They live a purely pastoral life, and, perhaps more than any other people in the world, are absolutely dependent for their existence on one animal,—the buffalo. Though they live in a fertile land and a delightful climate, they grow no crops, and have no kind of cultivation whatever. Though their woods and hills abound in game, they neither hunt nor trap any living thing. They keep no domestic animals but the buffalo and the cat, although the populations around them possess goats, pigs, and poultry. They eat no flesh, not even that of the buffalo, of which they often have a superabundance, but live wholly on milk and butter, with rice and such other vegetable food as they obtain in exchange for their surplus dairy produce and for the young male buffalos for which they have no use. Although surrounded by strong and often quarrelsome tribes, they possess no single weapon of offence or defence,—no bow, or spear, or sword, or club. They never fight among themselves or with their neighbours. They have no sports of activity or skill. They have no manufactures, even of the simplest kind. Two men in every village are set apart for the dairy-work, leaving all the rest to lead an almost absolutely idle life! Yet they are by no means savages of a very low type. They are quiet and dignified in their manners, amiable in disposition, and very good-looking, the excellent photographs with which the book is copiously illustrated showing us intelligent and often handsome faces, in no way distinguishable from those of many of our own country people. They are courteous to strangers and to each other, and have an elaborate system of salutations and ceremonies. Their absolute dependence on the buffalo has led them to a form of religion in which this animal is the central figure. They have a sacred breed of cattle, which are distinguished by carrying bells; and hence ancient bells are sacred. The dairy is sacred. No one except the dairyman and his assistant may enter it. During the term of their office, these two men have to pass absolutely solitary and celibate lives, they and their implements being touched by no human being. The dairymen who have charge of the sacred herds are for the time being looked upon as gods. They keep in the dairy certain relics,—old cow-bells, knives, and axes,—which are in the highest degree holy, and which the dairyman, also priest, salutes with certain ceremonies every morning. The people in general also salute the rising and setting sun, and have certain vague notions of a future state.

Our author has minutely studied this curious people, and gives us interesting details of their every custom and ceremony, habit

and superstition; so that we obtain a complete picture of the entire course of their simple lives, and a considerable insight into their mental and moral nature. Perhaps with somewhat of a student's partiality for his favourite subject, he arrives at the conclusion that they are a very ancient people, and that their existing customs and mode of life have come down, almost unchanged, from a period more remote than those of any other race known to us. He has also gone with extreme minuteness into their social statistics, taking an accurate census of a number of villages, and obtaining the ages, sex, and relationships of every individual. The results are exhibited in a series of tables, from which some very curious conclusions are drawn. The primitive custom of the Todas was to kill all female children except one or two. This, of course, resulted in a superabundance of males, and hence arose the practice of polyandry, or of some women having two or more husbands, which practice continues to this day. Although infanticide of females has long entirely ceased, yet the number of males is still largely in excess. The census tables seem to show that considerably more male than female children are born; and it is very ingeniously argued that this is the necessary consequence of long-continued female infanticide. It is proved thus. The average Toda family is six children born to each woman. Now, if we take three women, the first of whom has six daughters, the second six sons, and the third three sons and three daughters, we shall be able to trace the effects of infanticide on the proportionate numbers of the two sexes. The first mother has to destroy four daughters, keeping only two. The second keeps her six sons. The third destroys two daughters, keeping three sons and one daughter. There will remain nine sons and three daughters, and these will be the parents of the next generation. But the majority of these will be derived from families which produced more males than females, and as such tendencies are hereditary, the constant preservation of a similar majority generation after generation will inevitably result in a male-producing race; and this peculiarity having been established by a long course of artificial selection, will continue to manifest itself for an unknown period after the depraved practice which gave rise to it has been abolished.

The view that close interbreeding is not *per se* injurious is strongly supported by the case of the Todas. From time immemorial they have married together in the same or adjoining villages, till they are all closely related in various degrees of cousinship; yet the people seem to be as a whole healthy and vigorous, and remarkably free from all those diseases supposed to be produced by close interbreeding. Out of a population of 196, only 2 were malformed.

Colonel Marshall is an ardent phrenologist, yet that despised science nowhere appears prominently in his book beyond the two

chapters which he devotes to it. He insists on the remarkable simplicity and uniformity in the form of the crania of savage races compared with those of civilised and highly complex nations like our own; and this agrees with the much greater uniformity in savage character, and the less frequent occurrence of men of exceptional mental peculiarities. The extreme care and minute accuracy with which all the facts relating to this interesting people have been investigated, should secure for the author the credit of impartiality in the table of the comparative development of the various phrenological organs in eighteen individuals (males and females), taken, he assures us, without bias of any kind. The comparison of the average character denoted by the table and the observed peculiarities of the race are very interesting; and we can hardly believe that so intelligent an observer and reasoner could have failed to discover the unreality of phrenology if it were so entirely destitute of truth as it is the fashion with scientific men to assume.

The skull of the Todas is extremely and universally dolichocephalic,—that is long in proportion to its width. This form is very characteristic of low types of man, unprogressive and unenergetic. The Ancient Britons, the Lapps, Fins, Siamese, and some others, are, on the other hand, highly brachycephalic, that is, the skull is short, and approaches the globular form. Now Colonel Marshall gives us a suggestive theory of the meaning of these marked differences of form, and we believe it is the first theory of the kind that has been advanced; for, while strenuously opposing phrenology, the craniologists of the present day have not made the slightest approach to a correlation of cranial form with national or individual character. Enormous collections of skulls have been made; they have been figured and measured with the most scrupulous accuracy; the various proportions of the different dimensions have been compared; the averages of different races have been taken,—and all with no result whatever! It is, indeed, pretty generally agreed that the higher and more civilised races have the larger brains, and therefore the larger crania; but as to why these crania should differ in form and proportion so widely as they do, we obtain no light whatever. Nor has the study of the anatomy of the brain led to any more definite results; and even the recent experiments of Professor Ferrier are capable of various interpretations, since, while the phrenologists see in them a confirmation of their own doctrines, Dr. Carpenter maintains that they support his view, which is that the higher intellectual faculties are situated in the back of the head, while the development of the forehead only indicates the predominance of faculties common to man and the lower animals!

According to modern phrenology, the group of organs situated at the sides of the head, and which thus give it breadth and fulness, are termed invigorating, being those which give the

desire for conflict; for overcoming obstacles; for the acquisition of property; for animal food, and for elaborate dwellings, tools, and weapons, and which also incite to cunning and treachery. Tribes which have these faculties in excess will, as a rule, be warlike, cruel, treacherous, thievish, ingenious in constructing their weapons, huts, and canoes; fond of animal food, and good hunters, and sometimes cannibals. Tribes in which they are markedly deficient, will generally be the reverse of all this, peaceful, mild, open, honest, idle, careless in their food, huts, and clothing, and with few tools and weapons. Of course the proportions of the various organs may vary indefinitely in either form of cranium, and thus some one or other of these characteristics may be wanting; but, making allowance for this, we see a marked difference between such narrow-headed races as the low Australians, and the much higher broad-headed Sandwich Islanders, or the mild, narrow-headed Esquimaux, and the very broad-headed, warlike Araucanians. Colonel Marshall believes that the broad-headed type has been developed in the struggle for existence, and has in most cases driven out the narrow-headed where the two have come into contact. It must be remembered, however, that either extreme is an inferior type, and that it is the well-balanced organisation, with a brain intermediate in form, if sufficiently large, that will progress most in civilisation, and will be able to rule and conquer, or exterminate either extreme type. The objection, therefore, brought by Mr. E. B. Tylor ("Nature," Dec. 11, 1873) against our author's view, that the comparatively narrow-headed Russians have subjugated many broader-headed Asiatic tribes, is not to the point. The Russians are more civilised, in a higher state of organisation and discipline; and it is this, not their individual energies, that has now rendered them superior to those Eastern hordes which, at an earlier period, when their state of civilisation was more equal, would probably have overcome them. The warlike and ingenious Arabs, Afghans, and Malays, are all markedly brachycephalic. Dr. J. B. Davis states that his extensive collection of crania shows that, in most cases, the female skull is more dolichocephalic than the male, but that among many of the African races the reverse is the case. This has an interesting bearing on the fact, so strongly insisted on by our reporters of the Ashantee war, that the African women are much more industrious and energetic than the men; while we know that in Africa alone there exists an effective female army. These are suggestive facts; and it is to be hoped that they will induce phrenologists to utilise our large collections of the crania of various races, for the purpose of working out in detail the peculiarities of national character as indicated by them. This should be done by actual calliper measurements of every organ where practicable, so as to introduce precision into the results. The author of the present volume could do no better service to

his favourite study than by applying himself to this work when he returns to Europe; and we hope he may be induced thus to bring prominently before the scientific world a study which the present writer believes to be founded inductively on a wide basis of observed facts, and calculated to be of immense importance in elucidating the mental nature of man, both individually and nationally.

In this short notice we have not been able even to allude to many of the interesting topics discussed by our author. His beautifully illustrated volume should be read by every one who desires to see how much valuable matter a man of genius may obtain during a few months' sick leave; and how much light may be thrown on curious social problems, and on the early history of mankind, by the careful study of a few scattered families of an almost extinct tribe of savages.

The Ocean: Its Tides and Currents, and their Causes. By William Leighton Jordan. Longmans, Green, and Co., 1873.

This is a most vexatious book. We cannot help admiring the industry with which the author has studied his special subject of ocean currents, and to a certain degree the originality of his method of treating it, but in the midst of this we are thrown back by the extravagance of originality and error, in the author's conceptions of the fundamental properties of matter, and the laws of motion. His great stumbling block is the pre-Newtonian idea that the *vis inertiæ* of matter is a continual striving for rest, or an internal resistance to the continuance of motion. He endows inertia with positive activity, and makes that activity all one sided, by representing it as an inherent property or force of matter which opposes all external force sproducing motion, but offers no opposition to the external forces which resist or destroy motion, or, to use his own words, "I have shown that *vis inertiæ* opposes motion in everything, and that its own inherent property of *vis inertiæ* must tend to bring a body to rest under any circumstances whatever, just as much, and in the same manner, as the action of any force from without; and, secondly, I have shown that, as regards the motions of the planets in their orbits, the centrifugal force which opposes the centripetal force of the bodies which compose the solar system one towards another, and all towards their common centre of gravity, is the force of astral gravitation opposing that of solar gravitation; so that in their courses they are borne smoothly along the lines of equlibrium lying between opposing forces of gravitation."

Mr. Jordan evidently imagines that the quantity of matter composing the stars compensates for their distance, and thus enables them to control the gravitation of the sun upon the planetary members of the solar system. This utter miscon-

ception of the quantitative force of gravitation due to its necessary inverse variation with the square of the distance vitiates completely all the reasoning based upon it.

A further confusion is introduced by another paradox, which appears to be of Mr. Jordan's own invention, viz., "the motive force termed *evanescence*." We are told that it implies a motion of the evanescing particles, and gravitation tending to cause contraction necessitates a motion of the remaining particles; and since contraction is a necessary consequence of evanescence, having effect wherever evanescence occurs, it must act towards every point from which evanescence acts, and thus divide the universe into separate masses, and also that "certain forces are in play, causing constant change of form and place; and to the combined action of these forces (to which no name has hitherto been given) I have applied the term evanescence."

In spite of these explanations and a good deal more of similar disquisition, we confess our inability to understand evanescence.

When, however, Mr. Jordan fairly plunges into his proper subject, the Ocean, and deals with the phenomena of its currents apart from his paradoxical notions of "inertia," &c., he displays an amount of careful study and research that render his errors concerning fundamental physical laws the more vexatious. Some of his critical discussions of the theories of others are as remarkable for their clearness as his exposition of his own theories are for their obscurity. The following passage is an example.

"It seems to me that the manner in which gravitation would tend to restore disturbance of the normal level, such as those indicated by Dr. Carpenter, would naturally be by tidal movements, or easy, imperceptible movements of the whole mass of water intervening between the higher and lower levels, the former sinking and the latter rising simultaneously, just as when a trough half full of water is tilted on one side, the level of the water is maintained, not by the surface water streaming over the lower side, but, excepting the effects of friction against the sides and bottom of the trough, by an equable motion of the whole mass of water."

"When a narrow channel lies between the higher and lower level, as in the case of the Mediterranean and Baltic, this movement would form a rush of water through the Strait, but not an upper rather than an under current. It so happens that, in both these cases, so elaborately considered by Dr. Carpenter, the higher level is also the lighter water; and, therefore, by Captain Maury's simple theory, the specific gravity is restored, or an increase of the difference prevented by the heavier water running as an under current towards the lighter, and the lighter as an upper current towards the heavier. Suppose that instead of the lighter water being at the higher level, as in these two cases, the heavier were so, will any one contend that the level would be restored by a surface current from the higher to the

lower level? Is it not evident that the sweeping assertion that differences of level will be restored by surface currents is a mistake? The course of currents, as the level is being restored, clearly depends upon the relative specific gravity of the water at the different levels. The heavier water will form the under current, and the lighter the upper, regardless as to which may be at the higher or lower level; and, if there be no difference of specific gravity, the level will be restored by a tidal movement forming a current through any narrow channel intervening, but not an upper rather than an under current. The systems of upper and under currents through the Straits of Gibraltar and the Sound are clearly the result of differences in specific gravity, as explained by Captain Maury's theory, which had better be left in its original simplicity, for this modification with which Dr. Carpenter has attempted to encumber it is not an improvement, but an erroneous complication."

Here we have the vulnerable point of Dr. Carpenter's modified resuscitation of the old theory of oceanic circulation clearly indicated, and a home-thrust of clear, sound reasoning fairly delivered through it. As this point is the very heart of Dr. Carpenter's contribution to the subject, the thrust is fatal. It is followed by further and equally clear and able discussion of the details of Dr. Carpenter's arguments, and of the theories of Maury, Rennell, Herschel, &c. This chapter xx. of Mr. Jordan's book is really excellent, and worthy of careful reading, but we fear that it will not receive the attention it deserves, on account of the bad impression or prejudice which the author's fundamental physical errors must induce.

Cosmical theories are always dangerous, and their proprietors are always subject to a greater or lesser amount of martyrdom. Even if the theory is sound, its owner must die in order to obtain its acceptance; and if it is wrong, as usually happens, it is liable to insinuate itself amidst all his sounder thoughts and positive researches, and poison or intoxicate his common sense itself. Even if he has the exceptional strength of mind necessary for keeping his great theory from this sort of usurpation, he is a suspected visionary, and his most sober speculations are unnoticed." We fear that Mr. Jordan will not escape these perils.

Outlines of Natural History for Beginners. Being Descriptions of a Progressive Series of Zoological Types. By H. Alleyne Nicholson, M.D., D.Sc., M.A., PhD., F.R.S.E., &c. London: Blackwood and Sons.

This is a clearly-written, unpretending sketch of the subject which it treats, and well adapted to its object, viz., to assist the teaching of zoology in schools. The mode of presenting the

subject differs somewhat from that which is commonly adopted. Instead of at first presenting a general view of the animal kingdom, and its greater divisions into sub-kingdoms, Dr. Nicholson at once describes the individual types representative of the smaller sub-divisions or classes, commencing with the Aniseba as typical of the class Rhizopoda, and so on up to the dog as the representative of the Mammalia. The sub-kingdoms are afterwards described in the concluding chapter. The types are well-selected, and their characteristic features plainly described, though, of course, only in outline, the reproductive organs and the more minute details of internal structure not being described, the attention of the pupil being directed to the conspicuous points of structure, more especially to those which are external.

It is doubtless more in accordance with strict philosophy to take details first, and then to pass from them to the broader generalisation; but, in teaching, this method is attended with some disadvantages. We think that, on the whole, it would have been better in a work of this kind to have commenced at first with an outline of the most general kind, and then to have filled it up with the matter which forms the bulk of this little work. The relations of the different classes to each other would have been better understood after the pupil had been made acquainted with the general characteristics and the broader distinctions between the sub-kingdoms. As it stands, the step by which he is carried from the Cephalopoda to the fishes is made no broader than that by which he passes from the Crustacea to the Arachnida. In a work of this kind, the greatest difficulty is to determine what should be omitted; and opinions must necessarily vary rather widely on this point. As an expression of our own opinion, we think that Dr. Nicholson might advantageously have told the school-boy and girl just a little about the predecessors of the present generations of animal life; for instance, when he tells them of the rarity of the Brachiopoda, and his reasons for selecting an Australian representative of this group, he might have referred to the comparative abundance of their fossil remains. Thus some of the ancient links between the fishes, reptiles, and birds might have been described just sufficiently to awaken the curiosity of the pupil and indicate the bearings of his present study upon that of the ancient history of our globe.

We are rather inclined to quarrel with the title of the book, as it sanctions and maintains the very narrow, popular fallacy of regarding zoology as the whole of natural history. "Outlines of Zoology" would have been a sounder and more expressive title.

Manual of Lunacy; a Handbook Relating to the Legal Care and Treatment of the Insane. By LYTTLETON S. WINSLOW, M.B., &c. With a preface by FORBES WINSLOW, M.D., &c. London: Smith, Elder, and Co.

NOT being learned in the law, it is with diffidence that we express an opinion upon the work before us. Still a careful perusal leads us to conclude that the author is thoroughly master of his subject, and that his book will be of great value to all those members of the medical profession who devote themselves to the care of the insane, or who are called upon to give evidence on the mental condition of persons accused of crime. The section on "Medical Evidence in Court" contains advice which may be useful to other scientific men as well as to physicians when they have the misfortune to appear as witnesses in a court of justice. The unfair stratagems of counsel in dealing with technical evidence are alluded to in a manner which some, doubtless, among our readers will be able to appreciate from personal experience.

The statistics on the varying amount of insanity and idiocy in different countries give wide scope for speculative inquiry. Why, for instance, should an Englishman or an Irishman be nearly five times more liable to insanity than an Austrian? Why, in the little German state of Oldenburg, should 1 in every 301 of the gross population be insane, whilst in Saxony the ratio is only 1 in 1427? Neither race, nor government, nor religion seems to offer any clue to such a discrepancy as the latter.

Introduction to the Study of Organic Chemistry. By H. E. ARMSTRONG, Ph.D., &c. London: Longmans and Co.

THIS volume belongs to the useful series of "Text-Books of Science" which Messrs. Longmans are at present bringing out. We cannot say that the work displays any very striking characteristics either for good or evil. The author, having first explained organic chemistry as the chemistry of carbon compounds, touches briefly upon formulæ, empirical and rational, and upon the action of various reagents upon the carbon compounds. He then passes on to the family of hydrocarbons, and considers the remaining groups of carbon compounds in their relation to the hydrocarbons. Those who take up this volume as a book of reference, and search in it for information concerning animal and vegetable substances of importance in nature or in the arts will find themselves disappointed. But to furnish such information is certainly no part of the author's plan. His object has been to describe only those compounds whose "relations to other well-understood bodies have been satisfactorily established." The work is in its nature systematic, and substances whose constitution and relations are unascer-

tained must, therefore, be left provisionally unnoticed. The more chemistry succeeds in developing itself as a primary and exact science, the more it must, of necessity, abandon the merely descriptive and concrete features which marked its earlier days. That by so doing it must lose a certain portion of its attractions, and appeal to a different class of minds, is undeniable. To the student prepared to accept these changes we believe that Dr. Armstrong's work will be of value.

The Birth of Chemistry. (Nature Series). By G. F. RODWELL, F.R.A.S., &c. London: Macmillan and Co.

Is a knowledge of the history of chemistry necessary? No, and yes! It is quite conceivable, for instance, that a man without any knowledge of the origin and early development of the science might be the most brilliant and successful experimenter,—the most accurate analyst the world has produced. Nor can it be contended that the practical applications of the science are in the smallest degree promoted by an acquaintance with its rise and progress. But it is difficult to comprehend the philosophy of chemistry, or to view it in its relation to other sciences, without an acquaintance with the rise, the reign, and the decay of the successive theories which have prevailed in past days. As a branch of culture and a means of intellectual discipline, the history of science may justly claim a high rank. It is with this view, evidently, that the author approaches his subject. "I have endeavoured," says he, in his preface, "to trace the rise and early development of a very old science, mainly that we may mark the attitude of thought which actuated the scientific mind in bygone times, and may thus be led to compare the ancient with the modern method of evolving ideas and building them up into a connected whole." The history of science is to be studied as a basis for the methodology of science. The author likens the development of chemistry to the erection of a house. "The time when the foundation-stone was laid is too remote to be even suggested; the basis of the edifice is sunk deep in Eastern soil; the walls were slowly and laboriously raised during the middle ages, and were completed by Lavoisier, Black, and Priestley." The similitude is, in one important sense, misleading. Successive generations of experimentalists and inquirers do not merely add to the works of their predecessors. As Mr. Rodwell has elsewhere shown, they pull down and rebuild; they modify, they transform. And ever as they execute such changes, they dream that their own work is final and unchangeable. The world has, not for the first time, had its "modern" chemical views taught from every professorial chair, and eagerly imbibed by crowds of students. But before half a century had passed, the "modern" had become obsolete, and had been swept into

the limbo of forgottenness. Mr. Rodwell pursues his subject no further than to the dawn of modern pneumatic chemistry,—the epoch of Hales and Boerhaave, Lemery and Mayow. He has produced a thoughtful, suggestive, and decidedly readable book, which we hope will be duly appreciated.

Elements of Chemistry, Theoretical and Practical. By W. A. Miller, M.D., LL.D. Revised by Herbert McLeod, F.C.S. Fifth edition, with additions. London: Longmans, Green, and Co.

"Look for it in Miller" we have repeatedly heard said, when some rather recondite piece of chemical information had been vainly sought for in more voluminous works, or in files of scientific periodicals. And very often in "Miller" the fact required was found. Hence it is no wonder that the "Elements" have gradually secured that place in the favour of students which, *consule Planco*, was held by Graham and Turner. That a new edition was required is, therefore, perfectly natural.

The revision which the work has undergone does not consist merely in the insertion of the most important novelties discovered since the appearance of the fourth edition, but in a re-arrangement of the non-metallic elements which the editor conceives will "facilitate the progress of the student in the theoretical part of the science."

Many of the compounds of carbon have been removed to an appendix, as also the section on gas-analysis. An account has also been given of the most recent researches in thermo-chemistry,—a subject which is attracting the attention of some of the ablest chemists of the day, and which promises to play an important part in the progress of the science.

The Preparation and Mounting of Microscopic Objects. By Thomas Davies. Second Edition. Edited by John Matthews, M.D., F.R.M.S. London: Robert Hardwicke. 1873.

The former edition of this valuable little work has long been known to microscopists for the eminently practical manner in which its special subjects are treated, making it one of the most useful aids to the student commencing microscopical work.

The new edition will by no means disappoint its readers, the added matter amounting to fifty-eight pages. It is much to be regretted that the state of the author's health has prevented his personal superintendence of the work, but he has an able editor in Dr. Matthews, in whose hands he placed his copious store of

material. The manuscript was also submitted to Mr. T. Charters White, late secretary of the Quekett Microscopical Club, who made several valuable additions.

The book commences with an introductory chapter by the editor, containing an account derived from various sources of reagents used in histological inquiries; this will be of especial value to those commencing the study of minute anatomy. The original beginning of the work now forms chapter ii., which, under the title of "Apparatus," treats upon the materials used in mounting objects, such as glass slides, covers, and the other necessaries of the microscopist's work-table; it is here, as elsewhere, evident that the writer has seen and done everything that he describes.

The chapter on "Dry Mounting," in addition to what might fairly be expected on the subject, gives a somewhat detailed account of such objects as require special treatment before mounting in this manner, such as the collection, preparation, and cleaning of Diatomaceæ the mode of treating deep-sea soundings, both of which subjects are very fully treated, and much other valuable information.

In the portion devoted to "Balsam Mounting" some useful hints are given respecting the preparation of crystals.

The much disputed matter of "Fluid Mounting" is very fully dealt with, the author not only giving his own experience but also that of many other eminent microscopists. The chapter on dissection will prove useful to those interested in the subject, and to the same class of students the very full account of the processes of injecting and staining tissues will be welcome.

Half-Hours with the Microscope. Being a Popular Guide to the Use of the Microscope as a means of Amusement and Instruction. By Edwin Lankester, M.D. Illustrated from Nature by Tuffen West. New edition, with a chapter on the Polariscope, by F. Kitton. London: Robert Hardwicke. 1873.

The principal new feature in this edition is the chapter on the Polariscope, a subject generally avoided by writers on the microscope; and as a natural consequence this valuable aid to histological researches is, in too many instances, looked upon as a mere toy: the few pages by Mr. Kitton will be a great help to those needing information respecting the use of their polarising apparatus. The "half-hours" are, "On the Structure of the Microscope," "With the Microscope in the Garden," "In the Country," "At the Pond Side," "At the Sea-Side," "Indoors," and "On Polarised Light." The work will be, as was the former edition, of great service in guiding young microscopists as to where they are to look for employment for

their instruments; those who are without friends of kindred pursuits, or have not access to any of the now numerous microscopical clubs, will find Dr. Lankester a useful guide, and it will be their own fault if they do not learn something.

With regard to the illustrations, the artist is so well known that comment is needless.

Evenings at the Microscope; or Researches among the Minuter Organs and Forms of Animal Life. By PHILIP HENRY GOSSE, F.R.S. New Edition, 1874. Society for Promoting Christian Knowledge.

ALL who know the works of this most agreeable writer will be pleased to find that a second edition of this well-known work has been required; Mr. Gosse writes as those only can who have examined for themselves the objects they are describing. The greater part of the illustrations are from drawings on wood by the author, and it is to be regretted that so little pains should have been taken in printing to do them justice.

The descriptions of the various objects are interspersed with the needful directions as to magnifying power and apparatus employed, as well as numerous hints for collecting; this is a matter too generally neglected in describing the results of microscopical observations: microscopists who are expert themselves are apt to suppose that everyone knows as a matter of course how to follow the author, who has probably in many cases arrived at his conclusions by some peculiar mode of operation. All praise is due to Mr. Gosse for his consideration of the wants of young students.

In describing the structure of wool, the author still adheres to the old theory that the felting qualities of wool are dependent upon the serrations, instead of the undulations or waves which are very evident in the finer kinds of wool, merino for instance.* If hair was of good felting quality in proportion to its superficial roughness, surely the bat's hairs with their whorls of scales, and the branched hairs of insects, would be the best of all materials for the manufacture of felt; such is, however, not the case.

The *Rotiferæ* are very fully described, and many interesting points of their structure and life-history elucidated. This class is one which the author has made a special study, and the chapter contains a selection from his numerous papers on the subject supplemented by his more recent observations.

As might be expected, it is in the portions of the work devoted to marine animals that this eminent sea-side naturalist gives the most interesting details; here he is perfectly at home, and it is

* See paper by N. BURGESS, Trans. Quekett Microscopical Club, vol. i., p. 25, in which the subject of felting is very fully treated.

evident that the reader is under the guidance of one who is familiar with the results of shore and dredge collecting, and long and patient aquarium observations.

A considerable space is devoted to the structure of insects. In remarking on their eyes and ears, the author writes: "It is not impossible, judging from the great diversity which we find in the form and structure of these and similar organs in this immense class of beings, compared with the uniformity that prevails in the organs of sense bestowed in ourselves and other vertebrate animals, that a far wider sphere of perception is open to them than to us. Perhaps conditions that are perceptible to us only by the aid of the most delicate instruments of modern science may be perceptible to their acute faculties, and may govern their instincts and actions. Among such we may mention, conjecturally, the comparative moisture or dryness of the atmosphere, delicate changes in its temperature, in its density, the presence of gaseous exhalations, the proximity of solid bodies indicated by subtle vibrations of the air, the height above the earth at which flight is performed, measured barometrically, the various electrical conditions of the atmosphere; and perhaps many other physical qualities which cannot be classed under sight, smell, taste, or touch, and which may be altogether imperceptible, and therefore altogether inconceivable by us."

It is to be regretted that the author should have contented himself with borrowing a cut on page 151, representing the proboscis of the blow-fly, instead of supplying a figure more in accordance with recent observations drawn by himself.

The work can be safely recommended as a guide to those really in earnest as to their microscopical studies, and will prove an admirable companion to those who take their microscopes to the sea-side during the approaching summer holidays.

A Handbook of Practical Telegraphy. By R. S. Culley, Member Inst. C.E., Engineer-in-Chief of Telegraphs to the Post-Office. Adopted by the Post-Office and by the Department of Telegraphs for India. Sixth edition, revised and enlarged. London: Longmans, Green, Reader, and Dyer. 1874. 8vo., pp. 443.

It is a sure sign of the high estimation in which Mr. Culley's work is held, and of the soundness of his electrical knowledge, when we find that his volume has already reached its sixth edition. Holding a foremost position in his profession, and surrounded by the whole telegraphic network of the British Isles, he necessarily constitutes the centre towards which a vast mass of electrical and telegraphic information naturally concentrates; and, as a consequence, his writings may be considered the digest of these experiences.

We are informed in the preface that many portions of the book have been re-written,—incumbent on the author by reason of the rapid extension of all the branches of the profession. So numerous have been the alterations and additions that we do not hesitate to state that the labour of passing the book through the press must have cost Mr. Culley great time and close application; in fact, as much as would be necessary to compile the whole volume. Amongst the extra matter, we find an important and lengthy chapter on the Duplex System, which will be eagerly read. In this chapter, the author undertakes the explanation of the question from the commencement; and in so clear and popular a manner does he carry the reader along with him through the different stages that everyone who studies the subject can most easily follow him. There are various methods of telegraphing by the duplex system, three of which are well known, viz., "the Bridge," "the Differential," and "the Leakage." The two former, however, are the systems that Mr. Culley has treated of; the third he does not refer to, because, as we suppose, he does not consider it of sufficient practicability to deserve attention. Students, however, we are sure, would have been glad to have had his experience on the subject, and to have had an explanation of the *modus operandi* from his pen.

The comprehension of the work is large and varied. It includes:—

Part I., Sources of Electricity. Part II., Resistance and the Laws of the Current. Part III., Magnetism and Electro-Magnetism. Part IV., Induction. Part V., Atmospheric Electricity and Earth Currents. Part VI., Insulation. Part VII., The Construction of a Line of Telegraph. Part VIII., Ordinary Testing. Part IX., Description of Instruments. Part X., Submarine and Underground Wires. Addenda of various useful tables of reference.

The same determination has guided Mr. Culley in this as in former editions; he has excluded from his work all theories based upon unproved hypotheses, and has thereby maintained its character as a "practical handbook" on all matters relating to the science of telegraphy. As a handbook it is unexceptional, and is rendered far more readable from the profuse illustrations interspersing the book at almost every page. Some idea may be formed of its rich endowment in this respect, when we mention that it contains over a hundred and fifty engravings, exclusive of nine full page illustrations, and six large folding plates of very useful designs. With such a work in his hands, we believe every operator on our lines, however backward he may be in his electrical knowledge, would soon acquire a sound acquaintance with the practice of the science, and to them, as well as to general scientific students, we heartily recommend the work.

Student's Class Book of Animal Physiology. By T. Austin Bullock, LL.D. London: Relfe Brothers.

The author tells us in his preface that "This book, whatever be its fate, has come of a careful and earnest endeavour to meet the requirements of higher and middle class schools, and of all teachers who may desire to prepare pupils for Government or other science examinations."

We quite believe in the care and earnestness of the manufacture of this book. Every page displays the result of careful and earnest cramming on the part of the author himself, and an equally careful and earnest effort to transfer the cram to his readers or pupils. The machinery by which he seeks to effect this is a series of questions followed by mechanical answers suitable for the requirements of those michievous people who call themselves teachers, and whose teaching consists in putting certain books in the hands of their unfortunate pupils, marking so many lines to be "got off by heart," and then listening to their misguided victims while they "say their lessons."

The following is a sample:—

Q. What are the names and positions of the interior bodies of the brain?"

"*A.* From the base upwards we have (1.) The Posterior and Anterior Pyramids, and quite close by the side of the latter are (2.) The *Olivary Bodies*, with the *Restiform Bodies* on their outer sides; (3.) The *Pons Varolii*, a mass of neurine an inch wide, with its fibres running like a bridge across the Medulla Ob.; (4.) The *Corpus Dentatum*, a mass of grey neurine with a tooth-shaped edge, in the anterior of that part of the cerebellum at the sides of the Pons; (5.) The *Crura Cerebri* (legs of the brain) rounded masses of nerve fibres, which, from the Medulla Ob., emerge at the upper end of the Pons; (6.) The *Corpora Albicantia*, two pear-shaped silvery bodies at the base of the brain, but connected with the cerebrum; (7.) The *Corpus Callosum* which unites the two hemispheres of the cerebrum; (8.) The *Pituitary Bodies*, between the *Olfactory Nerves;* and (9,) The *Tuber Cinereum* just under the latter (Fig. 25, V. between V and W; S.E.P.M.; Corpus Callosum between I. and G.; I. K).

Fig. 25, to which these utterly unintelligible references are made, is a representation of the *exterior* of the base of the brain. The next question is—

"*Q.* What are the other bodies in the interior of the brain."

This is answered in like manner by simply enumerating the Thalami, Corpora Striata, Corpora Quadrigemina, and the Commissures in the same parrot-like manner, and again referring to Fig. 25, in which *none of these "Bodies" are shown.*

This is all the information afforded on this part of the subject. Anybody at all acquainted with the structure of the brain may imagine the state of mind of the unfortunate pupil who strives to obtain any *ideas* from such a string of mere names. What must

be his notions of the anterior and posterior pyramids, of the legs of the brain, &c. ?

From this sample of anatomical exposition let us pass to one or two physiological disquisitions. The following is the answer to the question "What is the Sensorium?"

"That ideal point of the brain which the older physiologists, and some modern school books, call the *Sensorium*, and regard as the *seat* and *abode* of soul, is merely a fancy organ which has no existence; but the Sensorium of modern physiologists is a series of ganglionic centres at the base of the brain, including the *Olfactory Bulb*, or ganglion, and the auditory and optic ganglia."

The spinal cord is described as "the seat of a set of definite and combined muscular movements, which are altogether independent of sensation and volition; and it gives to the whole muscular mechanism a healthy contraction and tone, which at once disappear on its destruction."

"*Q.* What is the reason that certain kinds of animals live in the human stomach in spite of the powerful action of the gastric juice?

"*A.* On living substances the juice has no power, but it acts immediately after death, and it has been found that it sometimes dissolves and perforates the stomachs of the dead. Bone, even iron, and other metals gradually yield to its action; and there are instances of nails and clasped knives having been reduced to mere fragments in the human stomach."

Lesson 14 is headed "Gases in Blood." The first question of this lesson is:—"How is the colour of the blood affected by O and CO_2, and why is O constantly supplied and CO_2 as constantly thrown off?" This and the next question, "Why is CO_2 found in the blood, and how is it related to the temperature of the body?" are answered as though oxygen and carbonic acid gases are actually and abundantly mixed with the blood "thrown off," and circulate with it. In reply to the question, "What is the *exact* chemical composition of albuminous substances?" the pupil is told "that all these substances consist of C, H, O, N, S, and that some of them possess P in addition," and further on, that "gelatine consists of the same elements as albumen, but combined in smaller proportions." This style of actual looseness and inaccuracy, with affected technical profundity, prevails throughout, and is calculated, even where no actual blunders are made by the author, to convey most erroneous ideas to the pupil.

The author, in his preface, says, "We have dealt little in general description, or in those 'bird's-eye views' which try hard to exhibit all, succeed well in showing nothing. A really earnest student who prepares to meet remorseless examiners must see the subject not in bird's-eye view but from the plane of the facts and circumstances themselves." We pity any "earnest student"

who relies on this or any of the kindred works that are written by incompetent teachers for the mere purpose of cramming with phrases and technicalities in order to pass examinations. In the learning of languages, whether living or dead, this wretched method of packing the memory may be sufficient; but we warn all candidates for science examinations against any attempts to "get up" any branch of science by mere efforts of memory. Something higher than this is demanded of the scientific student. He must not merely learn his lesson,—he must understand his subject; for the remorseless examiner in science at once detects the ignorance of the candidate who merely answers by rote. If he is at all qualified to conduct a scientific examination, he will always include among his questions some theoretical and practical problems which ignominiously convict the crammed candidates, and he condemns their blunders far more remorselessly than the shortcomings of the conscientious student who has learned much less but understands a little more. A simple rudimentary treatise on physiology which, in the same space as the book before us, attempted to teach conscientiously and thoroughly about one-tenth of what is here pedantically heaped together, might enable a student to pass some of the more elementary examinations on physiology adapted to junior pupils; but this "Student's Class Book" is utterly worthless for the purpose of the "really earnest student," and can only serve as a delusion and a snare even to the student who is so misguided as to attempt to pass an examination in physiology by merely cramming the memory with technicalities and learned phrases.

A Treatise on Watch-Work, Past and Present. By the Rev. H. L. Nelthropp, M.A., F.S.A. London: E. and F. N. Spon. 1873.

Let no one suppose that it is the watch-maker alone who will be interested in this little treatise. Indeed we doubt whether the work will find much favour in the trade; for the reverend writer exposes so many of the malpractices of the watch-maker's craft that he will probably find himself as unpopular in Clerkenwell as Mrs. Stowe is said to have been in the Southern States after the publication of her anti-slavery novels.

During a century and a half, dating from about 1660, when Dr. Robert Hooke invented and applied the balance or pendulum-spring, the science of horology made great advances in this country. Those were the palmy days of watch-making when the workman took an intelligent interest in his work and sought to gain a reputation by the quality of his escapements. But, *tempora mutantur*, and at the present day our author maintains that there is not a rising man to lay claim to the sceptre of such makers as Mudge, Arnold, or Earnshaw, and that "in a few

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years it is not probable it will be possible to find in Clerkenwell a workman capable of doing first-class work." To remedy this lamentable state of things, Mr. Nelthropp suggests that it would be desirable to establish a school in connection with South Kensington, and to revive, in some measure, the powers of the Clock-makers' Company, so that members should be elected only after examination by a competent governing body.

Although watch-making seems to be falling into this state of decay in England, there are yet many amateurs who take great interest in the art. But with the exception of Mr. Denison's excellent "Rudimentary Treatise," published some years ago in Weale's series, we do not remember any modern English work on this subject.

After defining the terms used in watch-work, and describing the tools used by the watch-maker, Mr. Nelthropp presents the reader with a sketch of the history of time-keepers. "Le ciel est une horloge constante et perpétuelle," and therefore the sundial was the earliest form of time-piece. As to watches, the antiquary knows that they were first made by Peter Hele, of Nuremberg, about the year 1500, and were called—from their place of manufacture and from their shape—"Nuremberg eggs."

Passing from the historical to the technical portion of the work, we find rules for calculating the number of teeth of wheels and leaves of pinions, and the necessary calculations for trains. Descriptions are then given of the five principal scapements—the verge, the horizontal, the duplex, the lever, and the detached escapement. A translation of a treatise on the pitching of wheels and pinions, by the astronomer M. de Lalande, is given in the shape of an Appendix.

Although Mr. Nelthropp's volume is not the work of a man practically engaged in the trade, it may be recommended not only to the antiquary who delves into the history of the watch-maker's craft, but also to every intelligent person who seeks to know something about the anatomy of the little time-keeper which he carries in his pocket.

PROGRESS IN SCIENCE.

MINING.

Owing to the alteration in the system of collecting the Mineral Statistics of Great Britain, introduced by the new Mines' Regulation Acts, the publication of the last volume of Mr. Robert Hunt's valuable Statistics, giving the returns for 1872, was unavoidably delayed until so late in 1873 that we were unable to notice them in the last number of this Journal. The method of obtaining voluntary returns, originally initiated and for many years successfully carried out by the present Keeper of Mining Records, has been displaced by a compulsory system, under which the returns are forwarded, through the local Mining Inspectors, to the Secretary of State for the Home Department. It may be well to point out that the working of this system, in its present form, is fraught with much inconvenience. Thus, by a curious accident in the wording of one of the clauses of the Coal Mines' Regulation Act, no one, except the Inspector and the Home Secretary, is permitted to see the returns, unless express consent be given by the coal-owner. Hence the Keeper of Mining Records himself is actually shut out, in most cases, from consulting the very returns which it is his duty to collate and present, in an aggregated form, to the public.

One great cause of delay in the publication of the last volume of "Mineral Statistics" is attributable to the fact that, although the Metalliferous Mines' Regulation Act, 1872, requires that all returns shall be made to the Inspectors by the 1st of August in each year, yet many of the returns on this first occasion were not in the Inspector's hands until late in November. Moreover, the Act requires only a return of the ores raised, and consequently their value and percentage of metal have to be obtained from other sources. Mr. Hunt has therefore made use of the returns to the Stannary Court for the ores of Devon and Cornwall, and the Public Ticketings for the copper-ores sold in Cornwall and Swansea.

Following our usual course, we here present a general summary of the quantity and value of the minerals raised in the United Kingdom during the year 1872:—

	No. of Mines.	Tons.	Cwts.	Value.
Coal	3001	123,497,316	0	£46,311,143
Iron ore	266	16,584,857	0	7,774,874
Copper ore	117	91,983	0	443,738
Tin ore	162	14,266	0	1,246,135
Lead ore	455	83,968	3	1,146,165
Zinc ore	63	18,542	12	73,951
Iron pyrites (sulphur ore)	35	65,916	3	39,470
Arsenic	15	5,171	15	17,964
Wolfram	3	88	5	993
Cobalt	1	1	0	20
Manganese	3	773	0	38,865
Fluor spar	1	80	12	40
Ochres, umbers, &c.	5	3,326	15	8,227
Bismuth ore	1	2	0	—
Barytes and chloride of barium	26	9,157	17	7,208
Clays, fine and fire (estimated)	—	1,200,000	0	450,000
Other earthy minerals (estimated)	—	—		650,000
Salt	—	1,309,497	10	654,748
Coprolites (estimated)	—	35,000	0	50,000
Total value of minerals produced in the United Kingdom in 1872				£58,913,541

Under the name of the Aërophore, M. Denayrouze has brought out an ingenious apparatus for furnishing to the miner a supply of fresh air in the midst of a deleterious atmosphere. The air is compressed by a double-barrelled pump of peculiar construction, the cylinders being movable, whilst the pistons are fixed, thus reversing the usual arrangement. By means of a regulator the pressure of the air may be adjusted at pleasure. The miner inhales the air through an india-rubber mouth-piece, whilst a supply is delivered on similar principles to his lamp. The Denayrouze lamp is specially constructed to burn independently of the surrounding atmosphere, and derives its air solely from the lamp-regulator. In one form of the Denayrouze apparatus the air is compressed into strong reservoirs, at a pressure of 20 atmospheres. Experiments putting the apparatus to tests which seem to be sufficiently severe have recently been conducted in this country,—it is said with much success. No doubt such an apparatus might be of special service in re-opening a pit after an explosion, and before it is expedient to admit fresh air; but it is evident that apparatus of this kind can have but a limited application, and is not likely to be used for prolonged work.

To prevent the collier from tampering with his Davy-lamp, Messrs. Bailey and Waddington have patented the application of a seal to the locked lamp. This seal is enclosed in a case, and so arranged that the miner cannot unscrew his lamp and expose the light without breaking the seal, and thus convicting himself.

At a recent meeting of the North Staffordshire Institute of Mining and Mechanical Engineers, a paper was read, by Mr. T. M. Goddard, on "Better Communication in Pit-Signalling by means of Electricity." He described the system of electrical signalling employed with much success at the Goldenhill Colliery. This system was said to be much more economical than the ordinary method of using a stranded bell-wire, and not so liable to get out of repair. Moreover, less room is required in the shaft with this system.

The subject of coal-cutting by machinery was recently brought before the Cleveland Institution of Engineers, by Mr. J. S. Jeans, of Darlington. After tracing the history of such machinery, he described two of the most popular coal-cutters,—namely, Mr. W. Firth's machine, and the Gartsherrie coal-cutter of Messrs. Baird. The latter has been successfully working at the Hetton Colliery.

"An Essay on the Prevention of Colliery Explosions," by Mr. Emerson Bainbridge, of Sheffield, has appeared in the columns of the "Colliery Guardian." After enquiring into the cause of such accidents, the author examines how far the means now used for their prevention can be considered successful, and points out what he considers should be done by legislation and by mining-engineers to prevent such explosions, and to lessen their fatal effects when they do occur. Mr. Bainbridge's experience and position should secure a respectful attention to his views. This essay is one of those written in competition for the Hermon prizes. The three prize-essays—those of Mr. W. Galloway, Mr. W. Creswick, and Mr. W. Hopton—have been published in a separate volume. Another of the competitive essays, by Mr. J. Harrison, of Eastwood, Notts, has appeared in the "Mining Journal."

An "Official Report on the Coal-Fields of Victoria," prepared by Mr. J. Mackenzie, the Government Examiner of Coal-fields in New South Wales, has been recently issued. It contains a careful description of the several coal-deposits of the Colony, illustrated by sections, and offers suggestions where search should and should not be made for payable seams of coal.

Mr. H. B. Medlicott has published, in the "Memoirs of the Geological Survey of India," some "Notes on the Narbadá or Sátpúrá Coal-Basin." It seems probable that we have in this basin a more complete representation of the great plant-bearing rock-series of India than in any other part of the Peninsula. The writer advises that the experiment of boring for coal within the field, at a distance from the actual outcrop, should be made at Budi, in the Dudhi Valley.

The peculiar conditions under which diamonds occur in the fields of South Africa have been well described by Mr. E. J. Dunn, who, before his recent return to the Cape, contributed to the Geological Society of London an interesting paper on this subject. The so-called "dry diggings," such as the well-known Colesberg Koppje and Du Toit's Pan, are circular areas surrounded by horizontal shales. As to the diamond-bearing rock itself, Mr. Dunn describes it as an eruptive mass brought up to the surface through pipes which have penetrated the shales, and turned up their edges. On sinking into these pipes, the general sequence of deposits is—first, a few feet of sand; then, a layer of calcareous tufa; and this deposit passes gradually into an altered igneous rock, the true character of which is still an enigma. It has been suggested that it may be a gabbro or euphotide, serving as the base of a breccia which contains fragments of shale, dolerite, and other rocks. Can this euphrotide breccia be regarded as the actual mother-rock of the South-African diamonds?

METALLURGY.

Under the head of "Mining" we publish this quarter a summary of the "Mineral Statistics" for 1872, showing the quantities of ores raised in the United Kingdom during that year. In connection with these returns, and to show the position of our metallurgical industries, we may present the following statement, which exhibits the quantities and values of the several metals obtained from the ores raised in 1872:—*

	Quantity.	Value.
Pig-iron	Tons 6,741,929	£ 18,540,304
Copper	,, 5,703	583,232
Tin	,, 9,560	1,459,990
Lead	,, 60,455	1,209,115
Silver	Ozs. 628,920	157,230
Zinc	Tons 5,191	118,076
Other metals (estimated) ..	—	2,500
		£ 22,070,447

An interesting feature is this year introduced into the "Mineral Statistics," in the shape of returns giving the consumption of coal in our blast-furnaces. These figures show that the quantity of coal consumed, on an average, for every ton of pig-iron produced, in 1872, amounted to 51 cwts. The economy of our iron-masters becomes evident on remembering that it was computed by the Royal Coal Commission that 3 tons of coal were consumed per ton of pig-iron.

Mr. T. Hughes, of the Geological Survey of India, has contributed to a recent number of the Survey "Records" some notes on the "Iron-Deposits of Chándrá in the Central Provinces," in which he gives some interesting details respecting the relative amounts of ore and fuel ordinarily employed by the natives in their furnaces. The wealth of Chándrá in iron ores is considerable, and the value of the deposits is likely to be increased by the occurrence of coal in the neighbourhood. The native furnaces, though still liliputian, are larger than those commonly in use in Bengal, and several attain a height of nearly 6 feet. The section of the furnace is that of a cone; the hearth, as usual, slopes from behind forwards; the tuyeres are each 9 inches long, 1¼ inches diameter at the larger and ¾ inch at the smaller end; and the bellows are usually worked by hand. Taking the mean of several experiments, and reducing the weights to English units, we find that 8 tons of ore and 14¼ tons of charcoal are consumed in the manufacture of 1 ton of wrought-iron by this method.

* Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the Year 1872. With an Appendix. By ROBERT HUNT, F.R.S., Keeper of Mining Records. Longmans, 1873.

The Cleveland Institution of Engineers has been lately engaged in discussing Mr. Wood's methods of utilising blast-furnace slag. The slag is allowed to run from the furnace into water placed at the bottom of an iron drum rotating in a vertical plane. By this means the slag is disintegrated, and forms a powder called "slag-sand," which may be mixed with lime and used as mortar. The slag, in another of Mr. Wood's processes, is received on a flat, circular, rotating table of iron, where it is suddenly cooled, and spreads out into thin layers, which may be readily broken up and used in the preparation of concrete. Although there is perhaps no great novelty in Mr. Wood's methods, they are nevertheless likely to be of much value in using up a great deal of the Cleveland slag. In 1862 Mr. Gjers obtained a patent for running a stream of slag into water, but he allowed his patent to lapse. One great feature in Mr. Wood's machine is its economy of water. Mr. Jeremiah Head calculated that the cost of water would be only about $\frac{1}{10}$th of a penny per ton of slag disintegrated.

To determine the elasticity of metals, two different methods may be employed—either direct traction or transverse flexion. The discrepancy in the values obtained by these two methods in experiments with steel have been theoretically investigated by M. Peslin, in a paper, "Sur la Ténacité de l'Acier," published in a recent number of the "Annales des Mines."

In connection with this subject we may refer to a paper on "Tests of Steel," by Mr. A. L. Holley, read before the American Institution of Mining Engineers, in which the writer strongly condemns the practice of confining ourselves to mechanical tests, and staunchly advocates that all tested samples should be submitted to chemical analysis. In order that engineers may know what to specify, and that manufacturers may know what to make, a knowledge of the chemical composition of steel becomes absolutely necessary.

We observe that a paper "On the Molecular Changes produced in Iron by Variations of Temperature," by Prof. R. H. Thurston, of the Stevens Institute of Technology, has been reproduced in "Iron."

M. Pirsch-Baudvin has patented a new alloy, said to bear a strong resemblance to silver in many of its physical characters. A very white metal, forming a good imitation of silver, may be made of—Copper, 71; nickel, 16·5; cobalt, 1·75; tin, 2·5; iron, 1·25; and zinc, 7: about 1·5 per cent of aluminium may be added. In the preparation of this alloy certain precautions are necessary in the order and manner in which the constituents are mixed. The cobalt is said to determine many of the characters of this alloy.

The well-known "Revue Universelle des Mines, de la Métallurgie, des Travaux Publies, des Sciences, et des Arts appliqués a l'Industrie" is about to appear in an English dress. The proprietors have arranged for an English translation of each number, which will appear almost simultaneously with the French edition. This "Review" has recently contained a capital Report of the Liége Meeting of the Iron and Steel Institute.

MINERALOGY.

Corundum has been discovered, within the last two or three years, in deposits of considerable extent, and under conditions of unusual interest, at a locality, now known as Corundum Hill, in Macon County, North Carolina. Colonel Jenks, who discovered these deposits and has established workings for corundum at the Culsagee Mine, has recently visited this country, bringing with him a collection of specimens of great beauty and scientific interest. These have been submitted to the Geological Society, accompanied by notes on their mode of occurrence. It appears that the corundum is found in veins in a hill of serpentine, and is largely associated with chloritic minerals, such as ripidolite and jefferisite. Some of the crystals are notable for the intimate manner in which they are blended with these minerals, whilst others exhibit such brilliancy as to suggest that but little more is needed, in the way of purity of colour and freedom from flaws, to transfer them to the category of true gem-stones. It is hardly too much to expect that sapphires, rubies, and the

other valuable forms of alumina, may be yielded by the further working of these deposits. We understand that some of the crystals have been examined microscopically by Mr. H. C. Sorby.

For several years past Dr. F. A. Genth has devoted much attention to the study of *Corundum*, especially noting the characters of the associated minerals and the changes which corundum is supposed to undergo. The results of his studies have been published in the shape of the first part of the "Contributions from the Laboratory of the University of Pennsylvania." Although corundum has been found in America both in the Laurentian system and in rocks referred to the Taconic system, yet the greater part of the American corundum occurs in what is termed the chromiferous serpentine or chrysolite formation, and in the adjacent rocks. By comparing the associated minerals and the general conditions of occurrence of the emery and corundum of Asia Minor and the Grecian Archipelago with those of the most important American deposits, Dr. Genth is led to suggest a correspondence of geological age in the two cases. The author gives a long catalogue of minerals supposed to be produced by the alteration of corundum, and refers in some instances to true pseudomorphs as evidence of such changes. There are probably few geologists, however, who will be prepared to receive Dr. Genth's theory which seeks to explain the origin of certain beds of mica-schist, chlorite-schist, and paragonite-slate, by the alteration of larger deposits of corundum. Among the minerals associated with the American corundum are four described as new species, or varieties, under the names of *Dudleyite*, *Kerrite*, *Maconite*, and *Willcoxite*.

Dr. Fischer, well known for his microscopic studies of various minerals, has examined a number of specimens of so-called *Cat's-eye*; that is to say, quartz which presents, when polished, a curious band of light generally referred to the presence of enclosed fibres of asbestos. In all the specimens examined by Fischer he could find no trace of any fibres of asbestos, so that we are compelled to seek a new explanation of the fibrous character of the cat's-eye. The quartz may either possess a true fibrous structure of its own, or it may have replaced some mineral which originally possessed such a structure. It is the latter conclusion that Dr. Fischer is disposed to accept. This conclusion is interesting in connection with Wibel's examination of the cat's-eye of the Cape, noticed in last quarter's chronicles. Fischer's paper will be found in Tschermak's "Mineralogische Mittheilungen," published in Vienna.

A new mineral-species belonging to the group of felspars has been lately described by Von Kobell, in the "Journal für Praktische Chemie," under the name of *Tschermakite*, a name proposed in honour of Dr. Tschermak, who has done so much to simplify our views of this important group of rock-forming minerals. Tschermakite occurs at Bamle, in Norway, where it is associated with Kjerulfine. The new species is found in compact masses, with very perfect cleavage in two directions, making an angle of 94°. These cleavage-planes show fine striæ, similar to those on other triclinic felspars. Analysis gives—Silica, 66·57; alumina, 15·80; magnesia, 8·00; soda, with trace of potash, 6·80; water, 2·70=99·87. From this analysis may be deduced the formula $3(RO.\frac{1}{3}SiO_2)+Al_2O_3.3SiO_2$. Tschermakite may therefore be regarded as a peculiar species of felspar, related to oligoclase, but containing no lime.

An excellent monograph of the minerals grouped together under the general name of *Brochantite*, has been laid before the Vienna Academy by Dr. Schrauf, and published in its "Sitzungsberichte." He describes in much detail, and illustrates by admirable figures, the several forms of this mineral, of which four distinct types are recognised. It appears that Brochantite is not prismatic in crystallisation, but that most varieties are either monoclinic or triclinic.

The peculiar form of silica which Prof. Maskelyne some time ago discovered in the Breitenbach meteorite, and described under the name of *Asmanite*, has been recently studied by Prof. Vom Rath. His conclusions confirm those of Maskelyne, respecting the specific gravity, degree of hardness, and chemical

composition. Vom Rath's analysis gives—Silica, 96·3; ferric oxide, 2; magnesia, 1·1; lime, trace. There seems, therefore, no doubt that Asmanite is a new form of silica crystallising in the rhombic system, so that we are now acquainted with three species of crystallised silica, distinguished by their specific gravity in this wise :—

Quartz	sp. gr.	2·6
Tridymite	,,	2·3
Asmanite	,,	2·24

One of the rarest known mineral-species is *Roselite*, a substance determined by Levy in 1824, and named in honour of Gustav Rose. It appears that only two specimens are known, the one in the Werner Collection at Freiberg, in Saxony, and the other in the Turner Collection in this country. Both came from Schneeberg, in Saxony. Two new specimens, recently found at this locality by Herr Tröger, have been described by Prof. Weisbach.

A continuation of Rammelsberg's researches "On the Composition of the Natural Compounds of Tantalium and Niobium" has appeared in a recent number of "Poggendorff's Annalen." The present portion of the investigation relates to the minerals called pyrochlore, yttrotantalite, fergusonite, polyclase, euxenite, wöhlerite, samarskite, and æschynite.

Prof. Zepharovich has presented to the Vienna Academy a further description of his new mineral, *Syngenite*. He now finds that the species must be referred to the monoclinic and not to the rhombic system; that the artificial salt having the same composition (namely, $CaSO_4+Na_2SO_4+H_2O$) is also monoclinic; and that Rumpfe's mineral, *Kaluszite*, is in all probability identical with syngenite.

Dr. Burkart, of Bonn, has described in Leonhard and Geinitz's "Neues Jahrbuch" the mass of meteoric iron known as the Descubridora meteorite. This was found near Poblazon, in Mexico. The same mineralogist has a paper on the occurrence of the various minerals of tellurium and bismuth in the United States.

Among recently-published papers bearing as much on physics as on mineralogy, we may cite a memoir by Dr. Carl Klein, of Heidelberg, on the optical characters of the Epidote of Sulzbach; a paper by Prof. Nöggerath, of Bonn, on the phosphorescent glow exhibited by agates and other siliceous stones when ground on the large wheels used in the polishing-mills at Oberstein and Idar; and a paper by Dr. Behrens, of Kiel, on the spectrum of the precious opal.

ENGINEERING—CIVIL AND MECHANICAL.

Boilers.—At the present day when every manufacture is carried on with the aid of steam, the strength of boilers is a most important question with reference to the duty they are expected to perform. This, as a section of experimental science, has been very much neglected in this country. From an article which appeared in the "Nautical Magazine," on the United States Experimental Commission, it appears that the majority of the experiments made by Fairbairn, on the collapsing of tubes, and upon which a rule was based for the construction of steam-boilers, were with tubes of No. 19 wire gauge, or about $\frac{1}{32}$rd of an inch in thickness. According to the practical rule based upon these experiments, the strength against collapsing is directly as the square of the thickness, and inversely as the length, but the constant multiplier for collapsing pressure is given 71 per cent above the mean of the experiments, and 25 per cent above the maximum result obtained. Before September, 1871, Mr. Francis B. Stevens, of Hoboken, New Jersey, had made several experiments on the strength and proper management of boilers belonging to the United Railroad Companies of New Jersey; and so valuable did the results appear, that the Executive Committee of the United Companies voted 10,000 dollars for the continuance of the experiments, which were made on real boilers and with steam-power. The paper from which we quote was written before the completion of the experiments; but, so far as they had gone, they fully indicated

the danger produced by constructing a boiler so that the failure of any one stay would be fatal to the whole structure; and this is the more important since stays are seldom made to take the strain equally. The importance of the proceedings of this Experimental Commission was considered so great that the subject was brought before Congress, by whom 100,000 dollars have been voted to carry out similar experiments on a larger scale, and the Commission appointed for that purpose has made a beginning, but has not yet issued its report.

According to the report of the Midland Steam-Boiler Inspection and Insurance Company for the last half of 1873, they had 3555 boilers under their care, and during that period there had been no explosion of any boiler under their inspection. In consequence of the explosion of a blast-furnace boiler, attention has been directed to the safer working of such boilers of considerable length, it is suggested that they should be divided into separate lengths connected with narrow necks or pipe connections so arranged as to prevent rigidity. The feed water, in such case, would enter the back compartment and overflow into the next one, and then again into the front compartment, supposing the boiler to be in three compartments. The last compartment alone would require a water-gauge. The water, therefore, would gradually advance from back to front, while the heat would be greatest in the front. In this arrangement, apart from the diminished danger of explosion, it will be seen that the mud would be deposited in the back end, where, the heat not being sufficient to form it into a hard scale, it could be discharged by the blow-cock.

With regard to tube boilers, it is remarked that they can evidently be worked with success where the high pressure for which they were designed is required, and where good water can be obtained, but they do not offer much advantage for low pressure, or with the average scale making water. The experience of the past year confirms the opinion that no boiler is free from the danger of explosion if not well looked after; and that the best means of preventing explosion is to insist upon frequent inspection and careful attendants.

London Water Supply.—The Kent Company are now giving a constant supply to about 2200 houses in Deptford, and is extending the constant service to other parts of its district. The New River Company have now the power of affording effective constant service in their district; and they have also commenced a new high service covered reservoir, to contain one million gallons, at Southgate, in anticipation of the requirements of the water supply to Edmonton parish. This Company has, in a number of cases, afforded constant supply by means of stand pipes, and have agreed with a Committee of the Corporation of the City of London to furnish constant supply at once to a large number of the houses of the poor within the City bounds, wherever the arrangements of the officers of the Corporation in connection therewith are completed. The East London Company are extending the constant system of supply in their district, and have completed the arrangements for supplying the houses in one of their districts. The Southwark and Vauxhall Company are constructing covered service reservoirs at Nunhead, to contain 18,000,000 gallons, and are erecting additional engine power for high-pressure constant supply. Additional boilers and works are also being constructed at Hampton. The West Middlesex Company are giving constant supply to a number of houses on the application of the owners, who have provided fittings according to the Board of Trade Regulations. This Company is also constructing extensive works and additional engine-power at Hammersmith and at Hampton to ensure effective constant supply. The Grand Junction Company have completed a high service reservoir near Kilburn, to contain 6,000,000 gallons for constant supply, and have laid a line of main pipes to connect up this reservoir with the works at Campden Hill, and are likewise erecting additional boilers and works at Hampton. The Lambeth Company are also carrying out extensions and improvements to their Works. At Moulsey the construction of reservoirs is being proceeded with, to contain

110,000,000 to 120,000,000 gallons of water, with pumping engines to fill them to a level of 12 feet above the river. When full these reservoirs will contain ten to twelve days' water supply to the district. The water from the reservoirs will run by gravitation through the new conduit to the filters at Ditton, which are in course of extension by the conversion of the reservoirs there into filter beds. The Chelsea Company are proceeding rapidly with the construction of new filter beds at Ditton, and are laying down a new 30-inch pumping main between Kingston and Putney for the constant service supply, besides covering in a reservoir at Putney Heath—not hitherto in use—capable of containing 1,000,000 gallons of filtered water, to improve the supply of the high service.

Street Pavements.—Mr. Haywood, the Engineer and Surveyor to the Commissioners of Sewers of the City of London, in a recent report on the different kinds of pavement now in use, states that, from observations taken, it was found that, of "falls on knees," wood pavement had the greatest proportion, and that asphalt has the fewest of that class of accidents. Of falls on haunches, the asphalt had the largest proportion, and these accidents on it were very largely in excess of those on either of the other pavements, while the wood had the smallest proportion. Of complete falls there were fewest on wood and most on the granite, but the difference between the asphalt and granite was in this respect small. It appeared generally that horses travelling on the wood pavement were on the whole subjected to falls of a character less inconvenient to the general traffic in the street, and also less likely to be injurious to the horses, than those travelling on the other two pavements, and that in this respect the ligno-mineral was superior to the improved wood pavement. It was also noticed that, whatever was the nature of the accident, the horses recovered their feet more easily on wood than they did on either asphalt or granite. On the average of the observations made, the granite was found to be the most slippery, the asphalt the next so, and the wood the least. The conditions of the different pavements varied, however, in some respect with the state of the weather. Further observations than have yet been taken appear necessary before any final and conclusive judgment can be given for or against any one class of pavement.

Steam Economy.—On the 28th of January last Mr. Spence exhibited to a distinguished audience, at Stafford House, a plan by which he proposes to employ the heat of waste steam as a substitute for fuel. This method is founded upon a discovery made by the father of the inventor, that steam liberated at atmospheric pressure, and passed into any saline solution having a boiling temperature higher than that of water, would raise this saline solution to its own boiling-point. In utilising the exhaust steam from a high-pressure engine, Mr. Spence brings it into contact with a solution of caustic soda, which it will raise to a temperature of 375 degrees, or thereabouts, and the heated solution is then circulated through pipes in an ordinary boiler, and its heat is radiated for the purpose of generating steam in the place of heat derived from fresh fuel.

Brighton and Hove Gas-Works.—A paper on this subject was recently read before the Institution of Civil Engineers, by Mr. John Birch Paddon. The site of these works is the widest, most level, and highest part of a tract of shingle lying between the sea and the canal forming the eastern entrance to Shoreham Harbour. This shingle was formerly arrested in its eastward movement by the entrance-works to the harbour, but since the construction of the present westerly entrance it has been greatly wasted by the sea. Between 1865 and 1870, in front of the site of the gas-works, the high-water mark advanced landwards 100 feet. To obtain a deposit of shingle along the sea-front, as a protection, two groynes were first constructed, and others were subsequently built along the coast to be protected. The foundations of the walls of the buildings are laid on concrete, and so extended as to make the proportion of the weight of the superstructure to the bearing surface of 15 cwts. per square foot. The concrete bed under the retort benches is 7 feet 6 inches thick. The retort-house is 286 feet 6 inches long and 80 feet wide.

The chimneys are constructed with the lower parts of brick and the upper parts of wrought-iron, and are sufficiently light to be placed on the benches, so that no floor space is occupied by them: they are 71 feet 6 inches high, 3 feet square at the bottom, and 3 feet in diameter at the top, the least sectional area giving 1 square inch for each lineal foot of retort—a proportion which has proved satisfactory. There are twenty-four benches of retorts, each bench having eight long retorts, there being two mouth-pieces to a retort, or 384 mouth-pieces in all. The retorts are cylinders, 16 inches in diameter and 20 feet long, and each retort will carbonise 1 ton of coal per day. Allowing one-sixth as the number for reserve, the remainder will produce 1,500,000 cubic feet of gas every twenty-four hours, or 300 millions per annum. The engine-house contains four exhausters, each exhauster being driven directly by an independent engine. The entire cost of the works has been about £72,000; and when a proposed second retort-house and coal-store are erected upon the site allotted for them, the total expenditure will amount to £100,000. The works will then be capable of producing 600 millions cubic feet of gas per annum, at a cost of £166 per million on the capital expended.

Concrete Blocks.—The use of concrete blocks, of large size, in the construction of marine works, has, within recent years, come to be greatly extended. An interesting paper, "On the Construction of Harbour and Marine Works with Artificial Blocks of Large Size," by Mr. B. B. Stoney, formed one of the subjects under discussion at the Institution of Civil Engineers last February. The author described a new method of submarine construction with blocks of masonry, or concrete, far exceeding in bulk anything hitherto attempted. The blocks are built in the open air, on a quay or wharf, and, after from two to three months' consolidation, they are lifted by a powerful pair of shear-legs, erected on an iron barge or pontoon. When afloat, they are conveyed to their destination in the foundations of a quay wall, breakwater, or similar structure, where each block occupies several feet of the permanent work, and reaches from the bottom to a little above low-water level. The superstructure is afterwards built on the top of the blocks, in the usual manner. By this method the expenses of coffer-dams, pumping, staging, and similar temporary works are avoided, and economy and rapidity of execution are gained, as well as massiveness of construction, so essential for works exposed to the violence of the sea. There is now being built in this manner an extension, nearly 43 feet in height, of the North Wall Quay, in the port of Dublin. Each of the blocks composing the lower part of the wall is 27 feet high, 21 feet 4 inches wide at the base, 12 feet long in the direction of the wall, and weighs 350 tons. The foundations for the blocks are excavated and levelled by means of a diving-bell. The hull of the floating shears is rectangular in cross section, 48 feet wide, and 130 feet long. The aft end forms a tank, into which water is pumped to balance the weight of the block suspended from the shears at the bow of the vessel.

Dublin Water Supply.—"The Water Supply of the City of Dublin" formed the subject of a paper, by Mr. Parke Neville, at the Institution of Civil Engineers, on the 24th of February. The water supply of the City of Dublin was for several centuries derived from the River Dodder. In 1775 this source was found to be insufficient, and the Corporation entered into contracts with the then Grand Canal Company for a supplemental supply, which were extended in 1808. The water from this source was hard and subject to pollution, and from 1850 to 1857 the question of obtaining a better supply was constantly under consideration. This ultimately led to the appointment of a Royal Commission, and Sir John Hawkshaw was appointed by the Government as Commissioner. The result of his enquiries was the recommendation of the River Vartry as the best source, and works for that object were commenced in November, 1862, and finished in 1868. The Vartry rises at the base of the Sugar-Loaf Mountain, in the county of Wicklow, and the place selected for the storage reservoir is near the village of Roundwood, about 7½ miles below the source of the river. The embankment across the valley, at its deepest point, is 66 feet high, and its total length is 1640 feet. The

greatest depth of water impounded is 60 feet, and the average depth 22 feet. The area of the reservoir is 409 acres, and it is capable of holding 2400 million gallons of water, equal to two hundred days' supply for the city of Dublin and suburbs. Two mains, 48 inches and 33 inches in diameter respectively, are carried through the bank, in a tunnel excavated out of the rock, and arched over. The 48-inch main, which terminates in the bye-wash, is a provision solely for the purpose of being able rapidly to lower the water in the reservoir, if necessary. The 33-inch main conveys the water to a circular receiving-basin, situated at the outer toe of the embankment, and from this basin the water is distributed by side canals on to seven filter-beds. After being filtered, the water is collected into two pure-water tanks, from whence it is carried for about 700 yards in an iron pipe, 42 inches in diameter, with a fall of 6 feet per mile, until it reaches the tunnel, into which it is laid for 120 yards. The tunnel is 4367 yards long, and conveys the water from the natural valley of the Vartry, under a range of hills separating that valley from the districts sloping towards the sea to the east. This tunnel is from 5 feet to 6 feet high and 4 feet wide, with a gradient of 4 feet in a mile. At Callow Hill, the northern or Dublin end of the tunnel, there is a circular receiving-tank, 90 feet in diameter, from which a main, 33 inches in diameter, conveys the water to the distributing reservoir at Stillorgan a distance of 17¼ miles. Three tanks relieve the pressure at different points, viz., at Kilmurray, Kilcroney, and Rathmichael. The water is distributed through the streets of the city by mains varying from 27 inches to 18 inches in diameter, which form a zone round the central parts of the city, from which the service-mains diverge. Screw-valves at the intersection of the streets enable the water to be turned off or on, either to repair the mains or to concentrate the pressure in case of fire. Hydrants are placed in every street at intervals of 100 yards, and the system is so perfect that since the introduction of the Vartry water no steam or hand fire-engine has been used to extinguish fires. The total cost of the works has been £610,000, or at the rate of about £1 16s. 6d. per head of the population.

Great Basses Lighthouse.—In 1855 instructions were given for the preparation of a design for the erection of a beacon on the Great Basses Rocks, off the coast of Ceylon. The design submitted was for a cylindrical cast-iron tower, secured within an enlarged basement of masonry, which basement was to be enclosed within an outer casing of cast-iron, and both tower and casing were to be sunk into the rock. After three years' operations, and the expenditure of £40,000, only a few landings had been effected on the rock, and the authorities therefore suspended further proceedings. In June, 1867, the whole question was referred to the Trinity House authorities, who recommended for approval a design prepared by their Engineer, Mr. J. N. Douglas, for a granite structure in which the base of the former structure was proposed to be utilised. The lighthouse, which has now been constructed, consists of a cylindrical base, 30 feet in height and 32 feet in diameter, on which is placed a tower, 67 feet 5 inches in height, 23 feet in diameter at the base, and 17 feet in diameter at the springing of the curve of the cavetto. The thickness of the wall is, at the base of the tower, 5 feet, and at the top 2 feet. The accommodation within consists of six circular rooms, each 13 feet in diameter; and there is also a room, 12 feet in diameter, in the basement, for coals and water, and a rain-water tank below, 7 feet 6 inches in diameter. The tower contains 12,288 cubic feet of granite, and the cylindrical base 25,077 cubic feet, making a total of 37,365 cubic feet, weighing about 2768 tons. Above the tower is a lantern and dioptric revolving apparatus of the first order. The cylindrical 14-feet lantern of the Trinity House has been adopted. The dioptric apparatus has eight panels of refractors, with upper and lower prisms for emitting flashes of red light at intervals of 45 seconds. A 5-cwt. bell, for a signal during foggy weather, is fixed on the lantern gallery. The cost of the building was £64,300, and the light was first exhibited on the 10th of March, 1873, and has since been regularly continued every night from sunset to sunrise.

GEOLOGY.

Physical Geology.—Perhaps the most important contributions to geological science made of late years are the observations of Mr. J. W. Judd, on the "Ancient Volcanoes of the Highlands, and their Relations to the Mesozoic Strata," which he has recently communicated to the Geological Society of London. The vestiges of the secondary strata on the west coast of Scotland have been preserved, like the interesting relics of Pompeii, by being buried under the products of volcanic eruptions. The deposition of these strata was both preceded and followed by exhibitions of volcanic phenomena on the grandest scale. The rocks forming the great *plateaux* of the Hebrides are really the vestiges of innumerable lava-streams, and it is proved that these lavas were of sub-aërial origin, by the absence of all contemporaneous interbedded sedimentary rocks, by the evidently terrestrial origin of the surfaces on which they lie, and by the intercalation among them of old soils, forests, mud-streams, river-gravels, lake-deposits, and masses of unstratified tuffs and ashes. Mr. Judd points out that the great accumulations of igneous products, which in places exhibit a thickness of 2000 feet, must have been ejected from great volcanic mountains, and in the course of his observations he has endeavoured to determine the sites of these old volcanoes, to estimate their dimensions, to investigate their internal structure, and to trace the history of their formation.

Origin of Lake Basins.—Mr. J. Clifton Ward, in discussing the origin of the basins of Derwentwater, Bassenthwaite, Buttermere, Crummock, and Loweswater, pointed out that they were not moraine-dammed lakes, but true rock-basins, and, considering all the features they presented, he was of opinion that the immediate cause of the basins was the onward movement of the old glaciers in the neighbourhood, ploughing up their beds to the comparatively slight depth of the basins which now form the lakes.

Geological Record.—A Record of Geological and Palæontological Literature is being carried out under the direction of the British Association. It is to embrace brief abstracts of all papers published abroad or in the provinces, and will appear regularly in the "Geological Magazine," after which it will be issued in a separate form. Two parts appear in the February and March numbers of the Magazine.

Mr. Whitaker has rendered great service to geologists by preparing lists of papers published on the Geology, Mineralogy, and Palæontology of different counties and districts. He has published those relating to Devonshire, the Hampshire Basin, and Cambridgeshire.

Geology and Parish Boundaries.—The relation of the parish boundaries in the south-east of England to great physical features, and particularly to the chalk escarpment, is a subject to which attention has been called by Mr. Topley. He has shown how the earliest settlements, and the manorial and parochial boundaries, have been dependent upon the original state of the country, whether wooded or open land, and upon the easily accessible water-supply, features which are intimately connected with geological structure.

Palæontology.—Mr. Henry Woodward has described a new star-fish, *Helianthaster filiciformis*, from the Devonian rocks of Harbertonford, South Devon.

Mr. A. Wyatt Edgell has made some additions to the list of fossils from the Budleigh-Salterton pebble-beds. These include species of *Modiolopsis*, *Sanguinolites ?*, *Aviculopecten*, *Pterinea*, *Palæarca*, *Avicula*, *Cleidophorus ?*, *Lunulocardium*, *Ctenodonta*, and *Orthonota ?* The peculiar assemblage of fossils found in the pebbles of this triassic bed was first pointed out by Mr. Vicary, whilst Mr. Salter assigned their parentage to beds on the coast of France. Mr. Edgell notices the accordance between many of the pebbles of Budleigh-Salterton and beds occurring on the opposite side of the Channel, in Brittany. In the discussion which took place after the reading of his paper at the Geological Society of London, Mr. Godwin-Austen observed that, in the same manner as the shingle of Lake Superior is carried away and re-deposited by

shore-ice, so he thought it possible that some action of the same kind might —during a portion of the New Red Sandstone period—have drifted materials off from the French shore of the Triassic lake, and deposited them in this shingle-bed at Budleigh-Salterton.

Dr. H. A. Nicholson has for some time been engaged in collecting and studying the organic remains of the Corniferous limestone and Hamilton formation of the western portion of the province of Ontario, which are considered to be of Devonian age. These deposits are richly fossiliferous: the total number of species comprised in his collections amounts to about 160 or 170, of which between 30 and 40 are apparently new. Of this number no less than 75 are corals, about 40 are Brachiopods, and the remainder are distributed amongst the *Polyzoa*, *Gasteropoda*, *Lamellibranchiata*, *Annelida*, *Trilobita*, and *Crinoidea*.

Diamonds in South Africa.—The occurrence of diamonds in South Africa has during the past few years attracted a considerable amount of public attention. Mr. E. J. Dunn observes that they occur in peculiar circular areas, which he regards as "pipes," which formerly constituted the connection between molten matter below and surface volcanoes. The surrounding country consists of horizontal shales, through which these pipes ascend nearly vertically, bending upwards the edges of the shales at the contact. Mr. Dunn is of opinion that the rock of the pipes was only instrumental in bringing the diamonds to the surface, a large proportion of them being found in a fragmentary state. Prof. Tennant has stated that during the month of November, 1873, no less than £100,000 worth of diamonds were brought from South Africa by three persons. At present about twenty thousand persons are employed in the diamond-fields, and he considers the stones equal to any in the world.

Sub-Wealden Exploration.—In regard to the progress of this boring, Mr. Henry Willett reports (Feb. 12) that the new contractors (the Diamond Rock-Boring Company) are putting forth great energy and skill in the prosecution of their enterprise, so as to make him very sanguine that nothing but want of money will prevent the exploration being extended, if found necessary, to 2000 feet. A depth of 350 feet has now been reached, and the rock there obtained is still Kimeridge clay. We understand that Mr. W. Topley, of the Geological Survey of England, is now resident near the spot where the boring is being made, to examine the specimens as they are brought to the surface.

Proposed Channel Tunnel.—Mr. Prestwich has lately reviewed the geological conditions affecting the construction of a tunnel between France and England, which subject, it will be remembered, was discussed not long ago by Mr. Topley in the "Quarterly Journal of Science." Mr. Prestwich pointed out the geological features of all the strata between Harwich on the one side, and between Ostend and St. Valery on the other side of the Channel, and stated his opinion that the most feasible plan, and one that would be perfectly practicable, so far as safety from an influx of sea-water was concerned, was to drive a tunnel through the Palæozoic rocks under the Channel between Blanc Nez and Dover.

Geological Society of London.—At the anniversary meeting of the Geological Society, held on February 20th, the Duke of Argyll announced the award of the Wollaston Gold Medal to Professor Heer, of Zurich, in acknowledgment of his extensive researches in fossil botany and entomology. The balance of the proceeds of the Wollaston Donation Fund was given to Dr. H. Nyst, of Brussels, in recognition of his admirable researches upon the Molluscan and other fossil remains of his native country. The Murchison Medal was awarded to Dr. Bigsley in recognition of his long and valuable labours in that department of geology and palæontology with which the name of Murchison is more particularly connected. The balance of the proceeds of the Murchison Geological Fund was divided between Mr. Ralph Tate and Mr. Alfred Bell as a testimony of the value set by the Society upon their palæontological researches. John Evans, Esq., F.R.S., &c., was elected as President for the ensuing year.

PHYSICS.

Microscopy.—The Quekett Microscopical Club has recently been presented with a series of insect preparations in balsam, from Ceylon. They are remarkable, inasmuch as the usual eviscerating and laying-out processes have not been adopted, but the insects mounted as much as possible in their natural position, and with the minimum amount of compression: the preparations are in many cases very thick, but this is no disadvantage, but rather the contrary, for observations with low powers and the binocular microscope. The insects were merely dried between the leaves of a book, and then mounted in balsam, sometimes after a soaking in turpentine; *liquor potassæ* has in no instance been employed. The hardening of the balsam has been effected entirely by exposure to the sun; the collection is totally free from milkiness from damp, and the penetration of the balsam is perfect. This mode of preparation is, of course, only available in tropical climates. Such preparations would probably be best made here by drying the insects by immersion in absolute alcohol, then soaking in oil of cloves, and, when the preparation has cleared, mounting in balsam. This process is much used on the Continent for anatomical subjects, frequently stained and injected, and is but little known in this country: it will be found invaluable where other modes of drying cannot be made available.

In illustrating a paper on the "Life-History of Monads," read before the Royal Microscopical Society, the Rev. W. H. Dallinger, F.R.M.S., executed the drawings in a manner which rendered them available for lecture illustration with the magic-lantern. The material chosen is finely-ground glass, upon which the drawing is made as readily as upon paper: the camera-lucida, or other instrument, is available for obtaining the sketch from the microscope. The pencils used should be harder than those employed in drawing upon paper; the engraver's 6H will prove useful, HB being strong enough for the deepest shadows. When the drawing is finished, it is to be rendered transparent by the application of Canada balsam, thinned with benzol to the consistence of cream: this is poured on the plate, and evenly distributed, somewhat in the manner of collodion in photography. When hard, the varnished surface is protected from injury by a glass fastened on it by strips of paper at the edges, with small pieces of card at the corners to prevent contact. Water-colour is available upon the ground-glass surface. The process will be found in every way easier than the usual mode of producing magic-lantern slides, and equally effective.

The "Sand-blast" process has been successfully employed by Mr. H. F. Hailes, of the Quekett Club, for excavating hollows in glass slides to be used as cells. For dry mounting they answer admirably, and the roughness of the bottom is no hindrance to mounting objects in balsam, as the lower surface of the cell is rendered perfectly transparent by contact with the mounting material.

Messrs. Underhill and Allen communicate to the March number of "Science Gossip" the following formula for glycerin jelly:—"Soak ½ oz. best amber gelatin (as sold by the chemist or grocer) in 1 oz. distilled water; when it has absorbed all the water, put it in a Florence flask with 50 grains of powdered chloride of barium; warm it in a water-bath, and agitate till the barium salt is dissolved. Allow it to cool below 35° C., and while still fluid add 1 oz. of Price's glycerin and a teaspoonful of white of egg; shake until well mixed, replace in the water-bath, and boil at full speed until the albumen *completely* separates from the jelly in the form of a single lump. Now filter through well-washed fine flannel, and it should be as clear as crystal; but if through mismanagement it be a little cloudy, filter it again, this second time using filtering-paper, and placing the funnel with the jelly, &c., in a '*cool*' oven. During the coagulation of the albumen, the jelly must on no account be stirred. It is well to beat up the white of egg before use, lest it should be stringy. The jelly made after this recipe is of the proper consistency for entomological objects, but for delicate vegetable structures it should be softened by adding to it a third of its volume of a mixture of equal parts of glycerin

and distilled water. Put the jelly into test-tubes ½ inch in diameter, and when you wish to mount a slide warm the upper part of the tube: in this way you can pour out any quantity free from bubbles. It is perhaps well to put a trace of varnish, or some essential oil, on the corks, lest they should get mouldy. The chloride of barium prevents fungi in the jelly, and is the best preservative we know of; but something is absolutely necessary. By all means avoid putting alcohol, creosote, &c., in the jelly, as they dissolve varnishes, and also spoil the colour of some objects." The hints on mounting in this paper are of great value.

An object-glass of American manufacture has arrived in London, engraved "R. B. Tolles, Boston. Immersion, ⅛th. 180°!! Balsam angle, 98." It performs well, defining splendidly, but is wanting—as are some good English objectives—in flatness of field. Why stop at 180°? Surely an enlightened citizen of a free and independent country will not be trammelled by the laws of mathematics and optics.

Heat.—In a paper communicated to the Royal Society, "On the Action of Heat on Gravitating Masses," the Editor of this Journal has recorded experiments which arose from observations made when using the vacuum-balance, described by the author in his paper "On the Atomic weight of Thallium,"* for weighing substances which were of a higher temperature than the surrounding air and the weights. There appeared to be a diminution of the force of gravitation, and experiments were instituted to render the action more sensible, and to eliminate sources of error. After an historical *résumé* of the state of our knowledge on the subject of attraction or repulsion by heat, the author describes numerous forms of apparatus successively more and more delicate, which enabled him to detect, and then to render very sensible, an action exerted by heat on gravitating bodies, which is not due to air-currents, or to any other known force. The following experiment with a balance made of a straw beam with pith-ball masses at the ends enclosed in a glass tube, and connected with a Sprengel pump, may be quoted from the paper:—"The whole being fitted up as here shown, and the apparatus being full of air to begin with, I passed a spirit-flame across the lower part of the tube at *b*, observing the movement by a low-power micrometer; the pith-ball (*a*, *b*) descended slightly, and then immediately rose to considerably above its original position. It seemed as if the true action of the heat was one of attraction, instantly overcome by ascending currents of air. . . . 31. In order to apply the heat in a more regular manner, a thermometer was inserted in a glass tube, having at its extremity a glass bulb, about 1½ inches diameter; it was filled with water, and then sealed up. . . . The water was kept heated to 70° C., the temperature of the laboratory being about 15° C. 32. The barometer being at 767 millims., and the gauge at zero, the hot bulb was placed beneath the pith-ball at *b*. The ball rose rapidly; as soon as equilibrium was restored, I placed the hot-water bulb above the pith-ball at *a*, when it rose again, more slowly, however, than when the heat was applied beneath it. 33. The pump was set to work, and when the gauge was 147 millims. below the barometer, the experiment was tried again; the same result, only more feeble, was obtained. The exhaustion was continued, stopping the pump from time to time, to observe the effect of heat, when it was seen that the effect of the hot body regularly diminished as the rarefaction increased, until when the gauge was about 12 millims. below the barometer the action of the hot body was scarcly noticeable. At 10 millims. below it was still less; whilst when there was only a difference of 7 millims. between the barometer and the gauge, neither the hot-water bulb, the hot rod, nor the spirit-flame caused the ball to move in an appreciable degree. The inference was almost irresistible that the rising of the pith was only due to currents of air, and that at this near approach to a vacuum the residual air was too highly rarefied to have power in its rising to overcome the inertia of the straw beam and the pith balls. A more delicate instrument would doubtless show traces of movement

* Phil. Trans., cxliii., part 1, p. 277.

at a still nearer approach to a vacuum; but it seemed evident that when the last trace of air had been removed from the tube surrounding the balance (when the balance was suspended in empty space only), the pith-ball would remain motionless wherever the hot body were applied to it. 34. I continued exhausting. On next applying heat, the result showed that I was far from having discovered the law governing these phenomena; the pith-ball rose steadily, and without that hesitation which had been observed at lower rarefactions. With the gauge 3 millims. below the barometer, the ascension of the pith when a hot body was placed beneath it was equal to what it had been in air of ordinary density; whilst with the gauge and barometer level its upward movements were not only sharper than they had been in air, but they took place under the influence of far less heat; the finger, for example, instantly sending the ball up to its fullest extent." A piece of ice produced exactly the opposite effect to a hot body. Numerous experiments are next given to prove that the action is not due to electricity. The presence of air having so marked an influence on the action of heat, an apparatus was fitted up in which the source of heat (a platinum spiral rendered incandescent by electricity) was inside the balance-tube instead of outside it as before; and the pith-balls of the former apparatus were replaced by brass balls. By careful management, and turning the tube round, the author could place the equipoised brass pole either over, under, or at the side of the source of heat. With this apparatus it was intended to ascertain more about the behaviour of the balance during the progress of the exhaustion, both below and above the point of no action, and also to ascertain the pressure corresponding with this critical point. After describing many experiments with the ball in various positions in respect to the incandescent spiral, and at different pressures, the general result appeared to be expressed by the statement that the tendency in each case was to bring the centre of gravity of the brass ball as near as possible to the source of heat, when air of ordinary density, or even highly rarefied, surrounded the balance. The author continues:—"44. The pump was then worked until the gauge had risen to 5 millims. of the barometric height. On arranging the ball above the spiral (and making contact with the battery), the attraction was still strong, drawing the ball downwards a distance of 2 millims. The pump continuing to work, the gauge rose until it was within 1 millim. of the barometer. The attraction of the hot spiral for the ball was still evident, drawing it down when placed below it, and up when placed above it. The movement was, however, much less decided than before; and in spite of previous experience (33, 34) the inference was very strong that the attraction would gradually diminish until the vacuum was absolute, and that then, and not till then, the neutral point would be reached. Within 1 millimetre of a vacuum there appeared to be no room for a change of sign. 45. The gauge rose until there was only half a millimetre between it and the barometer. The metallic hammering heard when the rarefaction is close upon a vacuum commenced, and the falling mercury only occasionally took down a bubble of air. On turning on the battery current, there was the faintest possible movement of the brass ball (towards the spiral) in the direction of *attraction*. 46. The working of the pump was continued. On next making contact with the battery no movement could be detected. The red-hot spiral neither attracted nor repelled; I had arrived at the critical point. On looking at the gauge I saw it was level with the barometer. 47. The pump was now kept at full work for an hour. The gauge did not rise perceptibly, but the metallic hammer increased in sharpness, and I could see that a bubble or two of air had been carried down. On igniting the spiral, I saw that the critical point had been passed. The sign had changed, and the action was faint but unmistakable *repulsion*. The pump was still kept going, and an observation was taken from time to time during several hours. The repulsion continued to increase. The tubes of the pump were now washed out with oil of vitriol,* and the working was continued for an hour. 48. The action of the incandescent spiral was now found to be energetically *repellent*,

* This can be effected without interfering with the exhaustion.

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whether it was placed above or below the brass ball. The fingers exerted a repellent action, as did also a warm glass rod, a spirit-flame, and a piece of hot copper." In order to decide once for all whether these actions really were due to air-currents, a form of apparatus was fitted up, which, whilst it would settle the question indisputably, would at the same time be likely to afford information of much interest. By chemical means a vacuum was obtained in an apparatus so nearly perfect that it would not carry a current from a Ruhmffork's coil when connected with platinum wires sealed into the tube. In such a vacuum the repulsion by heat is decided and energetic. An experiment is next described, in which the rays of the sun, and then the different portions of the solar spectrum, are projected into the delicately suspended pith-ball balance. *In vacuo* the repulsion is so strong as to cause danger to the apparatus, and resembles that which would be produced by the physical impact of a material body. Experiments are next described in which various substances are used as the gravitating masses. Amongst these are ivory, brass, pith, platinum, gilt pith, silver, bismuth, selenium, copper, mica (horizontal and vertical), charcoal, &c. The behaviour of a glass beam with glass ends in a chemical vacuum, and at lower exhaustion, is next accurately examined, when heat is applied in different ways. On suspending the light index by means of a cocoon fibre in a long glass tube, furnished with a bulb at the end, and exhausting in various ways, the author finds that the attraction to a hot body in air, and the repulsion from a hot body *in vacuo*, are very apparent. Speaking of Cavendish's celebrated experiment, the author says that he has experimented for some months on an apparatus of this kind, and gives the following outline of one of the results he has obtained :—"A heavy metallic mass, when brought near a delicately suspended light ball, attracts or repels it under the following circumstances.

"I. *When the ball is in air of ordinary density.*

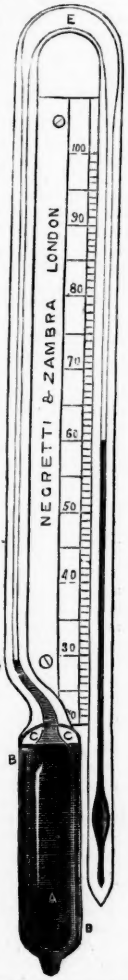
a. If the mass is *colder* than the ball, it *repels* the ball.
b. If the mass is *hotter* than the ball, it attracts the ball.

"II. *When the ball is in a vacuum.*

a. If the mass is *colder* than the ball, it *attracts* the ball.
b. If the mass is *hotter* than the ball, it *repels* the ball."

The author continues :—"The density of the medium surrounding the ball, the material of which the ball is made, and a very slight difference between the temperatures of the mass and the ball, exert so strong an influence over the attractive and repulsive force, and it has been so difficult for me to eliminate all interfering actions of temperature, electricity, &c., that I have not yet been able to get distinct evidence of an independent force (not being of the nature of heat) urging the ball and the mass together. "Experiment has, however, showed me that, whilst the action is in one direction in dense air, and in the opposite direction in a vacuum, there is an intermediate pressure at which differences of temperature appear to exert little or no interfering action. By experimenting at this critical pressure, it would seem that such an action as was obtained by Cavendish, Reich, and Bailey, should be rendered evident." After discussing the explanations which may be given of these actions, and showing that they cannot be due to air-currents, the author refers to evidences of this repulsive action of heat, and attractive action of cold, in Nature. In that portion of the sun's radiation which is called heat, we have the radial repulsive force possessing successive propagation required to explain the phenomena of comets and the shape and changes of the nebulæ. To compare small things with great (to argue from pieces of straw up to heavenly bodies), it is not improbable that the attraction now shown to exist between a cold and a warm body will equally prevail when, for the temperature of melting ice is substituted the cold of space, for a pith ball a celestial sphere, and for an artificial vacuum a stellar void. In the radiant molecular energy of cosmical masses may at last be found that "agent acting constantly according to certain laws," which Newton held to be the cause of gravity.

Messrs. Negretti and Zambra have recently communicated to the Royal Society the description of a new Deep-sea Thermometer. For the purpose of ascertaining the temperature of the sea at various depths, and on the bottom itself, a peculiar thermometer was, and is, used, having its bulb protected by an outer bulb or casing, in order that its indications may not be vitiated by the pressure of the water at various depths, that pressure being about 1 ton per square inch to every 800 fathoms. This thermometer, as regards the protection of the bulb and its non-liability to be affected by pressure, is all that can be desired; but unfortunately the only thermometer available for the purpose of registering temperature and bringing those indications to the surface is that which is commonly known as the Six's thermometer—an instrument acting by means of alcohol and mercury, and having movable indices with delicate springs of human hair tied to them. This form of instrument registers both maximum and minimum temperatures, and as an ordinary out-door thermometer it is very useful; but it is unsatisfactory for scientific purposes, and for the object which it is now used it leaves much to be desired. Thus the alcohol and mercury are liable to get mixed in travelling, or even by merely holding the instrument in a horizontal position; the indices also are liable either to slip if too free, or to stick if too tight. A sudden jerk or concussion will also cause the instrument to give erroneous readings, by lowering the indices if the blow be downwards, or by raising them if the blow be upwards. Besides these drawbacks, the Six's thermometer causes the observer additional anxiety on the score of inaccuracy; for, although we get a *minimum* temperature, we are by no means sure of the point where this minimum lies. Messrs. Negretti and Zambra have constructed an instrument on a plan different from that of any other self-registering thermometers. Its construction is most novel, and may be said to overthrow our previous ideas of handling delicate instruments, inasmuch as its indications are only given by upsetting the instrument. Having said this much, it will not be very difficult to guess the action of the thermometer; for it is by upsetting or throwing out the mercury from the indicating column into a reservoir, at a particular moment and in a particular spot, that we obtain a correct reading of the temperature at that moment and in that spot. The instrument has a protected bulb thermometer, like a syphon with parallel legs, all in one piece, and having a continuous communication, as in the annexed figure. The scale of this thermometer is pivotted on a centre, and being attached in a perpendicular position to a simple apparatus (presently described), is lowered to any depth that may be desired. In its descent the thermometer acts as an ordinary instrument, the mercury rising or falling according to the temperature of the stratum through which it passes; but so soon as the descent ceases, and a reverse motion is given to the line, so as to pull the thermometer to the surface, the instrument turns once on its centre, first bulb uppermost, and afterwards bulb downwards. This causes the mercury, which was in the left-hand column, first to pass into the dilated syphon bend at the top, and thence into the right-hand tube, where it remains, indicating on a graduated scale the exact temperature at the time it was turned over. The woodcut shows the position of the mercury after the instrument has been thus turned on its centre. A is the bulb; B the outer coating or protecting cylinder; C is the space of rarefied air, which is reduced if the outer casing be compressed; D is a small glass plug, on the principle of



Negretti and Zambra's patent maximum thermometer, which cuts off, in the moment of turning, the mercury in the column from that of the bulb in the tube, thereby ensuring that none but the mercury in the tube can be transferred into the indicating column; E is an enlargement made in the bend, so as to enable the mercury to pass quickly from one tube to another in revolving; and F is the indicating tube, or thermometer proper. In its action, as soon as the thermometer is put in motion, and immediately the tube has acquired a slightly oblique position, the mercury breaks off at the point D, runs into the curved and enlarged portion E, and eventually falls into the tube F, when this tube resumes its original perpendicular position. The contrivance for turning the thermometer over may be described as a short length of wood or metal having attached to it a small rudder or fan: this fan is placed on a pivot in connection with a second; on the centre of this is fixed the thermometer. The fan or rudder points upwards in its descent through the water, and necessarily reverses its position in ascending. This simple motion, or half-turn of the rudder, gives a whole turn to the thermometer, and has been found very effective. Various other methods may be used for turning the thermometer, such as a simple pulley with a weight which might be released on touching the bottom, or a small vertical propeller which would revolve in passing through the water. Messrs. Negretti and Zambra have also adopted a very simple and inexpensive clockwork to their thermometer, and by these means an observer may have a record of the exact temperature at any hour of the day or night. We need hardly say of what utility the instrument will prove to meteorologists, and even manufacturers, to whom an exact *record* of temperature is of importance. Hitherto we have had no simple and inexpensive instrument adapted for this purpose: the thermograph in use at most observatories is an elaborate and expensive apparatus, which, in connection with photography, will record on paper the temperature during day or night; it necessitates the use of gas, or any artificial light, and of course is only available to persons who can have a building specially adapted for it.

ELECTRICITY.—At a recent meeting of the Manchester Literary and Philosophical Society Professor Osborne Reynolds, M.A., read a paper "On the Bursting of Trees and Objects struck by Lightning." In a previous paper on this subject he stated that the tube which was burst by a discharge from a jar would probably withstand an internal pressure from 2 to 5 tons on the square inch; and he made use of the expression the tube might be fired like a gun without bursting. These statements were based on the calculated strength of the tube, and with a view to show that there was no mistake, the author tried it in the following manner:—He made three guns of the same tube. No. 1, which was 6 inches long, had its end stopped with a brass plug containing the fuze hole. Nos. 2 and 3 were 6 inches long, and had their breeches drawn down so as only to leave a fuze hole. These tubes were loaded with gunpowder and shotted with slugs of wire which fitted them, and which were all ¾ inch long. No. 1 was first fired with ¼ inch of powder, the shot penetrated ¼ inch into a deal board, and the gun was uninjured. No 2. was then fired with 1¼ inches of powder, and the shot went through the 1 inch deal board and ¼ inch into some mahogany behind, thus penetrating altogether 1½ inches; the tube, however, was burst to fragments. Some of these were recovered, and although they were small they did not show cracks and signs of crushing like those from the electrical fracture. No. 3 was then fired with ¾ inch of powder, and the shot penetrated ¼ inch into the deal board. It was again fired with 1 inch of powder, and the shot penetrated 1 inch into the deal. Again it was a third time fired with 1¼ inches of powder, when it burst, and the shot only just dented the wood. These experiments seem to prove conclusively the great strength of the tube and the enormous bursting force of the electrical discharge.

At the first meeting of the Physical Society of London the Chairman (Dr. Gladstone, F.R.S.) gave a brief description of the objects and organisation of the Society, and announced that ninety-nine gentlemen had already expressed their desire to join the Society as original members.

Mr. J. A. Fleming, B.Sc., read a paper on the "Contact Theory of the Battery." After discussing the most recent views regarding the contact and chemical theories, Mr. Fleming exhibited the action of his new battery, in which metallic contact of dissimilar metals is completely avoided. The battery consisted of thirty test-tubes of dilute nitric acid alternating with the same number of tubes of pentasulphide of sodium, all well insulated. Bent strips of alternate lead and copper connected the neighbouring tubes. By this device the terminal poles are of the same metal. On connecting with a coarse galvanometer, the needle was violently and permanently deflected. Tested by the quadrant electrometer, the potential was shown to increase regularly with the number of cells. The sixty cells on first immersion showed a potential exceeding that of 14 Daniell's cells. The principle upon which the action depends is that, in the acid, lead is positive to copper; in the sulphide it is negative. Mr. Fleming further showed how, by using the single liquid, nitric acid, and the single metal, iron, a single battery could be constructed, provided one-half of each iron strip were rendered passive. In this form, also, no metallic contact occurred.

Prof. F. Guthrie exhibited experiments illustrating the distribution of a galvanic current on entering and leaving a conducting medium. This was shown in the case of solids by the stratification of iron-filings on sheets of copper and lead. The effect of the distribution on a magnetic needle which is hung near a conducting vertical sheet in the magnetic meridian—into the upper horizontal edge of which a current enters, and out of which it passes at the same elevation—is to alter the direction of the needle's direction of turning, according as the needle is lowered or raised. At a distance from the upper edge of one-third the distance of the interval between the poles, the needle is at rest. A similar effect was shown in a liquid conductor.

The following are the officers of the Society for the first Session:—President, J. H. Gladstone, Ph.D., F.R.S. Vice-Presidents, Prof W. G. Adams, F.R.S.; Prof. G. C. Foster, F.R.S. Secretaries, Prof. E. Atkinson, Ph.D., York Town, Surrey; Prof. A. W. Reinold, M.A., Royal Naval College, Greenwich. Treasurer, Prof. E. Atkinson, Ph.D. Demonstrator, Prof. Frederick Guthrie. Other Members of the Council, W. Crookes, F.R.S.; Prof. A. Dupré; Prof. T. M. Goodeve, M.A.; Prof. O. Henrici; B. Loewy; E. J. Mills, D.Sc.; H. Sprengel, Ph.D.

Dr. Geissler, of Bonn, Germany, whose name is inseparably associated with some of the most beautiful experiments that can be performed by the agency of electricity, makes an electrical vacuum tube that may be lighted without either induction coil or frictional machine. It consists of a tube an inch or so in diameter, filled with air as dry as can be obtained, and hermetically sealed after the introduction of a smaller exhausted tube. If this outward tube be rubbed with a piece of flannel, or any of the furs generally used in exciting the electrophorus, the inner tube will be illumined with flashes of mellow light. The light is faint at first, but gradually becomes brighter and softer. It is momentary in duration; but if the tube be rapidly frictioned, an optical delusion will render it continuous. If the operator have at his disposal a piece of vulcanite, previously excited, he may, after educing signs of electrical excitement within the tube, entirely dispense with the use of his flannel or fur. This will be found to minister very much to his personal ease and comfort. He may continue the experiments, and with enhanced effect, by moving the sheet of vulcanite rapidly up and down at a slight distance from the tube. This beautiful phenomenon is an effect of induction.

In a note on a remarkable production of light in grinding of hard stones, Dr. Nöggerath refers to a visit made to some agate works at Oberstein and Idar, in which various kinds of hard stone are pressed by the workmen (with their hands) against quickly-revolving grindstones. The transparent stones become pervaded throughout with a yellowish-red light, like that of red-hot iron. Opaque stones give a red light at the place of contact, with halo and sparks. Dr. Nöggerath thinks the phenomena worth

studying by physicists, especially as regards development of heat and electricity.

In some researches on change in pitch of tones through movement of the source of sound, and determination, by this means of the velocity of sound, Dr. Schüngel experimented with two tuning forks, No. 1 giving 512, and No. 2 508 vibrations in a second, Sounded together they gave four beats in a second. But suppose No. 2 moved towards the observer (situated beside No. 1), its quantity of vibrations would be increased and the number of beats diminished. Dr. Schüngel sought to measure—(1) the time in which a certain number of successive beats was audible; and (2) the velocity of the moved fork. His apparatus (which was electrical) may be briefly described:—A seconds pendulum at each swing closed a circuit, which, through a relay, caused a series of dots to be marked on a telegraph strip at intervals corresponding to seconds. By pressing a key another battery circuit could be closed, which had two effects: part of the current went to the relay, and produced a line in the telegraph paper so long as the key was held down; but the greater part went through an electro-magnet, which attracted an armature at one end of a lever, having at its other end a roller rotated by a cord from a fly-wheel. The roller was thus pressed against the edge of a disc, which, thus set in motion, wound in, by a cord about its axis, a little wagon bearing the tuning fork (No. 2) with its case towards the observer. The method, with some suggested modifications, is commended to the attention of physicists for an accurate determination of the velocity of sound.

TECHNOLOGY.

Count Sokolnicki, a proprietor of vineyards at Medoc, states that a chemist, so-called, is selling to the wine-forgers of the Gironde a liquid of which a few drops suffice to colour a wine. An œnanthic liquor, simulating the bouquet of Medocs, is sold openly at Bordeaux. A solution of sugar is allowed to ferment on the pressed grapes, the colour and the flavour are added, and with these materials wines of the best growths are counterfeited.

For the manufacture of permanent beer M. Pasteur recommends the use of a pure yeast,—the mode of preparing which he does not describe,—free from vibriones, bacteria, *Mycoderma aceti*, &c. With such yeast, the process of fermentation can be carried on in the absence of air, or in the presence only of limited quantities of pure air. Beers thus made can, he declares, be preserved for an indefinite length of time, even at temperatures of 20° to 25° C.

M. Paul has effected an improvement in photo-lithography. He produces a positive image on paper covered with a layer of albumen mixed with a concentrated solution of bichromate of potash. After a sufficient insolation under the negative, the paper is covered with lithographic ink, and then immersed in cold water to dissolve the unaltered albumen.

As a test for the colouring matter of wines, M. de Cherville gives the following process:—Pour into a glass a small quantity of the wine under examination, and dissolve in it a morsel of potassa. If there is no deposit, and if the wine takes a greenish tint, it has not been artificially coloured. If a violet deposit has been formed, the wine has been coloured with elderberries or mulberries; if the deposit is red, beet-root or peach-wood has been used; and if violet-red, logwood. If the sediment is violet-blue, privet berries have been employed; and if a bright violet, litmus.

A paper "On Coloured Tapers," by Mr. James MacFarlane, Assistant to the Professor of Chemistry, St. Andrews, was recently read before the Chemical Section of the Glasgow Philosophical Society. The author detailed a series of experiments which he had prosecuted for the purpose of determining the nature of the colouring matter in the green and red wax tapers. He distinctly ascertained that the former owed their colour to the presence of Scheele's green (arsenite of copper). Their average weight was 2 grms., and the average time occupied in burning was seventeen minutes. Guided by the

colour and by the alliaceous odour evolved during combustion, he had no difficulty in pronouncing that arsenic was present; its presence was experimentally determined, and its quantity estimated to be 0·60 per cent of the taper, equal to 0·35 grm., or 5·43 grs. of arsenious acid—quite enough to poison two people if taken directly in the solid form. The red tapers weighed, on an average, about 8·94 grms., and burned seventeen minutes, leaving 3 milligrms. of ash totally devoid of metallic appearance. Mercury, existing as vermillion, was found by Reinsch's process, and its quantity was afterwards carefully determined. The amount of mercuric sulphide ultimately collected, washed, and dried, was 1·66 per cent. In one series of experiments the following results were arrived at—white, yellow, blue, red, and green tapers, being experimented upon:—

White.—Perfectly harmless; little ash.
Yellow.—Harmless; coloured with chromate of lead; ash, metallic.
Blue.—Harmless; coloured with ultramarine.
Red.—Highly poisonous, containing 1·93 per cent of vermillion; the tapers very highly coloured; slight ash.
Green.—Poisonous; colour due to arsenic; metallic ash; quantity of arsenic not determined, but probably about 1 per cent.

These tapers burned, on an average, twelve minutes, and in number and quality were much superior to the first, which were of the spiral character. The table is a summary of the results of the examination of the spiral tapers. The author afterwards proceeded to consider the effect arising, or which might arise, from the use of coloured wax tapers, and the inhalation of the vapours resulting from their combustion.

	Red.	Green.
Time occupied in burning	12 mins.	17 mins.
Weight	0·93 grms.	2 grms.
Percentage of wax	72·90	71·30
Percentage of wick	25·44	26·89
Weight of wax, per taper	24·85	22·53
Weight of wick, per taper	8·67	8·49
Percentage of arsenious acid	—	1·81
Percentage of vermillion	1·66 to 1·93	—

The same author submitted a communication on arsenical papers, in the course of which he reviewed the theories and cases for and against the alleged unhealthiness of rooms papered with hangings having Scheele's green as one of their colouring matters. He mentioned several cases of severe illness, and even of death, distinctly traceable to the inhalation of the green arsenical compound used in the preparation of the cheaper kinds of paper-hangings.

Referring to the opinion expressed by Mr. S. Barber on page 36 of the "Quarterly Journal of Science," for January, 1874, that mock suns outside the sun are an unusual phenomenon, Mr. T. W. Backhouse writes to say this is not the case, and that Flammarion's book, "The Atmosphere," states that mock suns are only on the halo when the sun is low, and that as its altitude increases they gradually emerge from it. With reference to the halo of 90°, which Mr. Barber says he believes is not seen in summer, our correspondent says that, if the halo about 90° *in diameter* is alluded to, he has seen it in summer, viz., in 1869, on June 11th and on August 10th. Both these days were, however, cool, with a maximum temperature of 58°.

LIST OF PUBLICATIONS AND PERIODICALS RECEIVED FOR REVIEW.

Cholera: how to Avoid and Treat it. By Henry Blane, M.D., M.R.C.S. *Henry S. King and Co.*

Catalogue of Stars observed at the United States Naval Observatory during the Years 1845 to 1871. Prepared by Prof. M. Varnall, U.S.N. *Washington: 1873.*

Treatise on Practical, Solid, or Descriptive Geometry. By W. T. Pierce. *Longmans and Co.*

The Naturalist in Nicaragua. By Thomas Belt, F.G.S. *John Murray.*

Personal Recollections, from Early Life to Old Age, of Mary Somerville. By her Daughter, Martha Somerville. *John Murray.*

The Galvanometer and its Uses: a Manual for Electricians and Students. By C. H. Haskins. *New York: D. Van Nostrand.*

Reliquæ Aquitanicæ; being Contributions to the Archæology and Palæontology of Périgord and the Adjoining Provinces of Southern France. By Edouard Lartet and Henry Christy. Edited by Thomas Rupert Jones, F.R.S., &c. *Williams and Norgate.*

Hydraulics of Great Rivers: the Paraná, the Uruguay, and the La Plata Estuary. By J. J. Révy, Memb. Inst. C.E., Vienna and London. *E. and F. N. Spon.*

Substance of the Work entitled "Fruits and Farinacea the Proper Food of Man. Edited by Emeritus Prof. F. W. Newman. *F. Pitman.*

Our Ironclads and Merchant-Ships. By Rear-Admiral E. Gardiner Fishbourne, C.B. *E. and F. N. Spon.*

The Nature and Formation of Flint and Allied Bodies. By M. Hawkins Johnson, F.G.S.

Legal Responsibility in Old Age. By George M. Beard, A.M., M.D. *New York: T. L. Clacher.*

An Elementary Treatise on Steam. By John Perry, B.E. *Macmillan and Co.*

The Psychology of Scepticism and Phenomenalism. By James Andrews. *Glasgow: J. Maclehose.*

Principles of Mental Physiology, with their Applications to the Training and Discipline of the Mind and the Study of its Morbid Conditions. By W. B. Carpenter, M.D., LL.D., F.R.S., &c. *Henry S. King and Co.*

Handbook of Natural Philosophy. By Dionysius Lardner, D.C.L. Edited by Benjamin Loewy, F.R.G.S. *Lockwood and Co.*

Inklings of Aërial Autonometry. By William Houlston. *Simpkin, Marshall, and Co.*

The Induction of Sleep and Insensibility to Pain, by the Self-Administration of Anæsthetics. By J. M. Crombie, M.A., M.D. *J. and A. Churchill.*

Elements of Physical Manipulation. By Edward C. Pickering. Part I. *Macmillan and Co.*

Principles of Mechanics. By T. M. Goodeve, M.A. *Longmans and Co.*

Cremation: the Treatment of the Body after Death. By Sir Henry Thompson, F.R.C.S., M.B., &c. *Henry S. King and Co.*

The Universe and the Coming Transits. By Richard A. Proctor, B.A. *Longmans and Co.*

PERIODICALS.

Macmillan's Magazine.

Naval Science.

The Popular Science Review.

The Geological Magazine.

The American Chemist.

The Westminster Review.

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